pulsAR Wireless Ethernet Bridge

Operator's Manual

Models: AR-9010E
AR-9027E
AR-24010E
AR-24027E
AR-24110E

January 2012

AFAR Communications Inc.
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Santa Barbara, CA 93117

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go the distance

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$25.00

Customer Service

AFAR provides customer service during normal U.S. Pacific Coast business hours and may be reached by voice, fax, or email as follows:

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Fax: +1 805 681 1994
email: support@afar.net

If you must return the equipment, please contact us for a Return Material Authorization (RMA) number. Equipment should be shipped to:

AFAR Communications Inc.
81 David Love Place,
Santa Barbara, CA 93117
U.S.A.

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This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

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Industry of Canada Notice

These devices have been designed to operate with two antennas each, listed on page 3-6, and having a maximum gain of 15 dBi at 900 MHz, or 24 dBi at 2.4 GHz. Antennas having a gain greater than the values above are strictly prohibited for use with these devices. The required antenna impedance is 50 ohms.

Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that permitted for successful communication.

TABLE OF CONTENTS

1 PRODUCT DESCRIPTION

1.1 Radio Overview

The family of *pulsAR* Wireless Ethernet Bridges consist of license free radios that can be used to bridge Ethernet LANs (Local Area Networks) across distances ranging from a few hundred feet to 50 miles (80 km) and beyond. You can deploy them in a variety of topologies from a simple point-to-point link to a general mesh “tree” topology where any subscriber node can also be used as an access point to nodes further downstream. For mobile applications you can configure subscriber nodes to autonomously roam between multiple access points, keeping the mobile nodes connected to the network at all times.

All radios use Direct Sequence Spread Spectrum and operate in the “Industrial Scientific and Medical” (ISM) bands, either at 900 MHz or 2.4 GHz. Table 1 shows the main characteristics of the 5 models. Refer to appendix B for the complete specifications.

Table 1.1: *pulsAR* radio models

Model number:	AR-9010E	AR-9027E	AR-24010E	AR-24027E	AR-24110E
Frequency Band (MHz)	902 to 928	902 to 928	2400 to 2483	2400 to 2483	2400 to 2483
Occupied Bandwidth (MHz)	1.7	4.6	1.7	4.6	17
Maximum data rate (Mbps)	1.1	2.75	1.1	2.75	11.0

The *pulsAR* radios are designed from the ground up to provide reliable wireless networks under adverse conditions, often encountered in the unlicensed bands. This includes the following features:

1. All the electronics are housed in an environmentally sealed enclosure rated for outdoor installation. You can mount the unit in close proximity to the antenna, which increases system performance by avoiding RF cable losses or expensive rigid coax cables. The radio is powered over the Ethernet cable.
2. Several models have an RF bandwidth that is much narrower than other unlicensed devices. This has several advantages, namely (i) the radio sensitivity is greatly improved allowing longer ranges, (ii) there is a much larger number of non-overlapping channels to choose from, and (iii) it is much easier to find an unused gap in a crowded spectrum.
3. For long range links in a crowded spectrum the most desirable receive frequencies at each end of the link are often different. In all p*ulsAR* radios the transmit and receive frequencies can be selected independently of each other.
4. The radio incorporates spectrum analysis and timing analysis tools, which allows you to quickly perform a survey of the RF environment without the need for spectrum analyzers.
5. Unique antenna alignment aid provides audio feedback proportional to the RSSI, freeing the installer’s hands to adjust and tighten the antenna without having to hold or look at other instrumentation.

The radios implements a transparent bridge algorithm, where each unit automatically learns the addresses of all stations in the network and forwards over RF only the traffic that needs to be delivered to the remote units. In the mesh tree network where packets may need to go through multiple hops, the radios always route the packets to reach their destination with the minimum number of hops.

If the application requires a serial synchronous interface, the radios can be paired with the Afar NetCrossing™ Gateway to provide both an Ethernet and a serial link of up to 2048 kbps across the same wireless connection. In this case the NetCrossing™ Gateway provides both the power and data to the radio across the single CAT5 cable. Refer to the NetCrossing™ Gateway Operator's Manual for complete details.

The *pulsAR* radios are the building block for the Afar "Synchronized PulsAR Network" (SPAN). In a SPAN network all radios synchronize their transmissions such that all co-located radios transmit and receive at the same time, thereby avoiding self-generated interference. This technique allows deploying large networks with upwards of 24 radios co-located without generating self-interference.

Each *pulsAR* radio can be configured over a local serial interface or over the Ethernet using an "Ethernet console" program provided by Afar. Once a unit is configured with an IP address you can also configure and monitor the unit using Telnet or SNMP. The radio firmware, in non-volatile memory, can also be updated remotely.

1.2 Radio Components

Table 1.1 below shows the part numbers of various accessories related with the *pulsAR* radio. You may have received some of these accessories bundled with your radios.

Table 1.2: *pulsAR* accessories

Description	Part No.
Bracket hardware for securing the *pulsAR* unit to an outdoor mast	KIT-0601
Bracket hardware for securing the *pulsAR* unit to a flat surface	KIT-0605
AC Power Inserter Module with 110-240 VAC power supply	
with a 6 ft USA 3-prong power cord:	PWI-0109-06A
with a 6ft European connector (Schuko) power cord	PWI-0109-06B
DC Power Inserter Module with pigtail for external DC connection	PWI-0209
CD with this Operator's Manual, Econsole program, and other application notes.	
Outdoor rated cat5 cable for connection between *pulsAR* radio and power inserter module (xxx is the length is feet)	CBL-0503-xxx
Auxiliary port cable for RS-232 connection (3 ft)	CBL-0403-003
Auxiliary port cable with Audio jack for antenna alignment	CBL-0404
Lightning arrestor for the antenna ports	SUR-0205
Surge suppressor for the Ethernet and Power CAT5 cable	SUP-0207

1.3 Radio Connectors

Figure 1.1 shows a *pulsAR* radio mounted on a mast. The radio is housed in a metal enclosure with two N-female connectors at the top for connection to RF antennas, and two special purpose connectors, at the bottom, for DC power, Ethernet data and control.

Figure 1.1: Pole Mounted Radio

The function of each connector is described in the table below.

Table 1.3: pulsAR Connectors

Connector	Type	Function
A	N-Female	RF connector to antenna A
B	N-Female	RF connector to antenna B (used in the tree topology)
C	Lumberg 3 pin male	Auxiliary port (3 pin) used as an antenna alignment aid and for RS-232 console port.
D	Lumberg 8 pin male	10/100 Base-T data interface and DC power input (8 pin). Must be connected to the "Power Inserter Unit" with a CAT 5 cable.

An eight-conductor CAT 5 cable must be connected between the *pulsAR* radio and either a Power Inserter Unit or an Ethernet port capable of providing Power over Ethernet (PoE) per IEEE 802.3af. The wiring for this cable is shown in Figure 1.3.

Table 1.4 shows the pin assignment of the three pin auxiliary port connector. The unit is shipped with a cover in this connector. The connector can be used during installation as a console port and also as an audio antenna alignment aid. There are two optional cables to convert from this non-standard 3-pin connector to either a DE-9 connector (for RS-232 console) or to a standard audio jack (for connection to a headphone). See Appendix D for cable diagrams.

Table 1.4 – Auxiliary Port Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Receive Data	RD	Radio Output
2	Transmit Data	TD	Radio Input
3	Ground	GND	

1.4 Radio Power

The pulsAR radio complies with the IEEE 802.3af Power over Ethernet (PoE) standard when power is applied over the data line pairs (pins 1-2 and 3-6). You typically can connect the radio directly to a PoE port of an Ethernet switch or router and it will provide power to the radio.

Figure 1.2 – DC (left) and AC Power Inserter Units

Alternatively the radio may also be powered over the spare cat5 line pairs (pins 4-5 and 7-8). On these lines the radio accepts a DC voltage over a very wide range (10 VDC to 58 VDC), allowing it to easily be powered by a 12 V battery. This method is not in compliance with the IEEE 802.3af mode B, which restricts the voltage range to 48 VDC.

Afar provides two Power Inserter devices (figure 1.2) that use this second method. One is for operation from an AC source (110-240 VAC), and the other for operation from a DC source (10 to 58 VDC).

The AC Power Inserter Unit includes a power supply for connection to an AC outlet (110-240 VAC). The DC Power Inserter Unit comes with a 10 ft pigtail for connection to your DC supply voltage. Both inserters have two RJ45 connectors and an LED. The two RJ-45 connectors are labeled “To LAN” and “To Radio”.

Table 1.5 – Power Inserter Units

Connector/LED	Type	Function
To LAN	RJ-45	10/100 Base-T to be connected to the Local Area Network. You can connect this directly to the LAN port of a computer or to an Ethernet hub. The radio auto-detects and provides the cross-over function when required. See table 1.5 for pin assignments.
To Radio	RJ-45	Carries the DC power and Ethernet signals to the radio. See table 1.6 for pin assignments.
LED (AC Power Inserter)	Amber/ Green	**Amber**: Indicates that the power inserter unit has power from the wall supply but no power is being drawn by the radio. **Green**: Indicates that the radio is drawing power.
LED (DC Power Inserter)	Green	Indicates that there is DC power in the pigtail input

WARNING

The Power Inserter connectors labeled “To radio” includes DC voltage in two of the pins. It must **not** be connected to a LAN as this voltage may damage some LAN cards.

Table 1.6 – "To LAN" Ethernet Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Ethernet Tx	Tx (+)	Radio to Ethernet(1)
2	Ethernet Tx	Tx (-)	Radio to Ethernet(1)
3	Ethernet Rx	Rx (+)	Ethernet to Radio(1)
4	(not connected)		
5	(not connected)		
6	Ethernet Rx	Rx (-)	Ethernet to radio(1)
7	(not connected)		
8	(not connected)		

(1) With auto-negotiation enabled the radio also provides an automatic cross-over function.

Table 1.7 – "To radio" Ethernet Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Ethernet Tx	Tx (+)	Radio to Ethernet
2	Ethernet Tx	Tx (-)	Radio to Ethernet
3	Ethernet Rx	Rx (+)	Ethernet to Radio
4	VDC	DCV (+)	Power Inserter to Radio
5	VDC	DCV(+)	Power Inserter to Radio
6	Ethernet Rx	Rx (-)	Ethernet to Radio
7	ground	GND(-)	Power Inserter to Radio
8	ground	GND(-)	Power Inserter to Radio

1.5 Outdoor Interconnect Cable

The interconnect cable between the Power Inserter Unit and the radio carries the following signals

1. DC voltage to supply power to the *pulsAR* radio.
2. 10/100 Base-T Ethernet data.

Both these signals are carried in a single CAT 5 cable. The system is designed to allow cable lengths in excess of the 100 meters (300 feet) of the IEEE Ethernet specification. Figure 1.3 shows the interconnect diagram for this cable and connector types. Table 1.8 lists a few part numbers and sources of appropriate CAT 5 cable for this application. Afar Communications Inc. carries several pre-made cables of different lengths. See Appendix D for connector diagrams, part numbers, and assembly instructions.

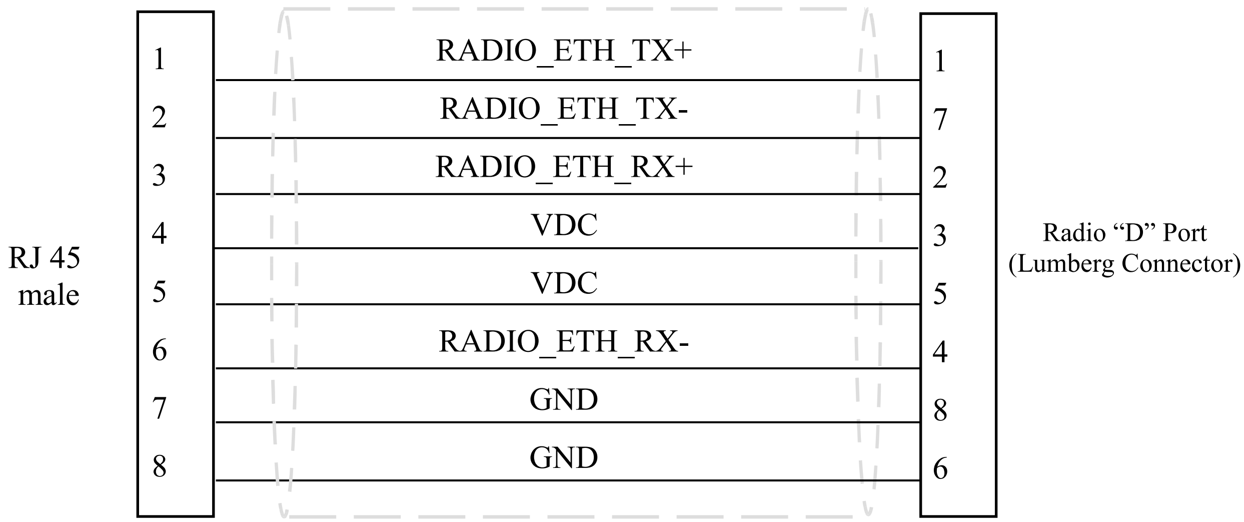


Figure 1.3 - CAT 5 Outdoor Interconnect cable diagram

Table 1.8 – Indoor/Outdoor Unit CAT 5 cable

Part number	Manufacturer	Description
7919A	Belden	Shielded outdoor rated cable
18-241-31(gray) 18-241-11 (beige)	Superior Essex	Unshielded outdoor rated cable
5EXH04P24-BK-R-CMS-PV	CommScope	Unshielded outdoor rated cable
2137113 (ivory) 2137114 (gray)	General Cable	Unshielded outdoor rated cable
BC1002	Belden	Unshielded outdoor rated cable

2 NETWORK TOPOLOGIES AND APPLICATIONS

2.1 Network Topologies

You can deploy the *pulsAR* radios in a variety of topologies from a simple point-to-point link to complex networks with multiple hops, redundant nodes, and mobile nodes. In all applications the radios will act as bridges connecting the LANs from all sites together. From any LAN you will be able to access stations at all other sites, even when they are several hops away. The radios will perform all the packet switching, sending packets in the appropriate direction so that they reach their destination with the minimum number of hops.

The following table lists the various topologies that are possible and gives you a brief description for each. Subsequent sections explain these topologies in more detail.

Topology	Description
Point-to-point	Single link between two points. For fixed sites use directional antennas to reach distances exceeding 80 km (50 miles).
Point-to-Multipoint	Central site with a single hub radio with links with up to 32 remote sites. The hub radio autonomously allocates bandwidth “on-demand” to each remote radio. You can co-locate multiple hub radios to increase total capacity or maximum number of remotes.
Point-to-Multipoint with Redundant Hubs	Two hub radios at the central site operating on different channels. The two hubs double the total throughput available but if one hub fails the other hub takes over and services all the remotes.
Tree topology	One **root** node with direct links to up to 32 remotes (like in point-to-multipoint). Any of the remotes can be promoted to a **branch**. A branch node operates as an access point for up to 32 additional remote nodes downstream (which can themselves be promoted to branch nodes). Radios come with two antenna ports, you can deploy a branch node with one directional antenna pointing at the parent, and a second omni antenna to serve as an access point.
Linear Network	Used for long networks with multiple stations along a railway, pipeline or roadside. Each node has at most two neighbors. Use the radio dual antenna port to deploy each radio with two directional antennas pointing at each neighbor.
Loop topology	Extension of the Linear Network with an additional link between the last node back to the first. Then, if any one link goes down the radios still keep connectivity between all nodes.
Roaming	Used with mobile nodes that move around an area with multiple fixed access points. The mobile radios change the access point automatically to keep you connected to the fixed network.

2.1.1 Point to point

In a point-to-point topology, when the two sites are fixed we recommend using directional antennas at both ends, pointing at each other. This increases the signal strength in the desired direction and shields the radios against unwanted interference from other sources. When you use directional antennas make sure you install both antennas with the same polarization (vertical or horizontal). Most often interfering sources are vertically polarized so you may want to install your link with horizontal polarization to get some additional isolation against those interference sources.

The point-to-point topology operates like a point-to-multipoint network where the hub has a single remote. You still need to configure one of the two radios to be the **hub** but configure it with the max number of children set to one. This optimizes the radio performance for point-to-point operation. See the **node** command in section 4.

2.1.2 Point to Multipoint

In a Point to Multipoint topology one radio is designated as the **hub** and all other radios are designated as **remotes**. You can have up to 32 remote nodes. You typically deploy the hub radio with an omni-directional or sectorial antenna so that it can cover all the remotes. If the remote sites are fixed deploy them with directional antennas pointing at the hub. If the remotes are mobile use omni-directional antennas everywhere.

Remote radios connect to the network automatically without need to change the configuration of the hub radio. All you need is to point an antenna at the hub and ensure that the following parameters are configured correctly:

1. The RF receive channel of the remote must match the transmit channel of the hub (see **rf-1-setup**).
2. The **network-id** parameter of the remote must match the network-id of the hub (see **node** command).
3. The **max-children** parameter at the hub must be large enough to give access to all the planned remotes (see **node** command).

There are situations when you may want to deploy multiple hub radios at the central site. These situations include:

- You need to increase total throughput of the central site.
- The number of remotes increases beyond 32.
- Provide hub redundancy.

In these situations configure each co-located hub to operate in non-overlapping channels. Refer to section 2.4 for additional guidelines on how to synchronize the transmissions from the multiple hubs.

For hub redundancy you need to configure the remote nodes to roam between the two channels used by the two hubs. You can split the remotes into two groups with one hub servicing each group. If one hub fails or there is strong interference in that channel, then the remotes will reattach to the other hub keeping the connection to the central site intact. Refer to section 2.2 for the roaming options.

2.1.3 Tree topology

In a tree topology you have three node types: one **root** node and multiple **branch** and **leaf** nodes (use the **node** command to configure the node type).

The **root** node performs a similar function to the hub in a point-to-multipoint topology and can have up to 32 direct links to remote sites. The radios at the remote sites can be configured as either **leaf** or **branch** nodes. A leaf node is similar to the remote in a point-multipoint topology. But a branch node, besides having a link to a **parent** (root or another branch), also operates as an access point for up to 32 additional remote nodes (**children**). Each of those nodes can again be configured as either a **leaf** or a **branch**. There is no limit to the number of levels in the tree.

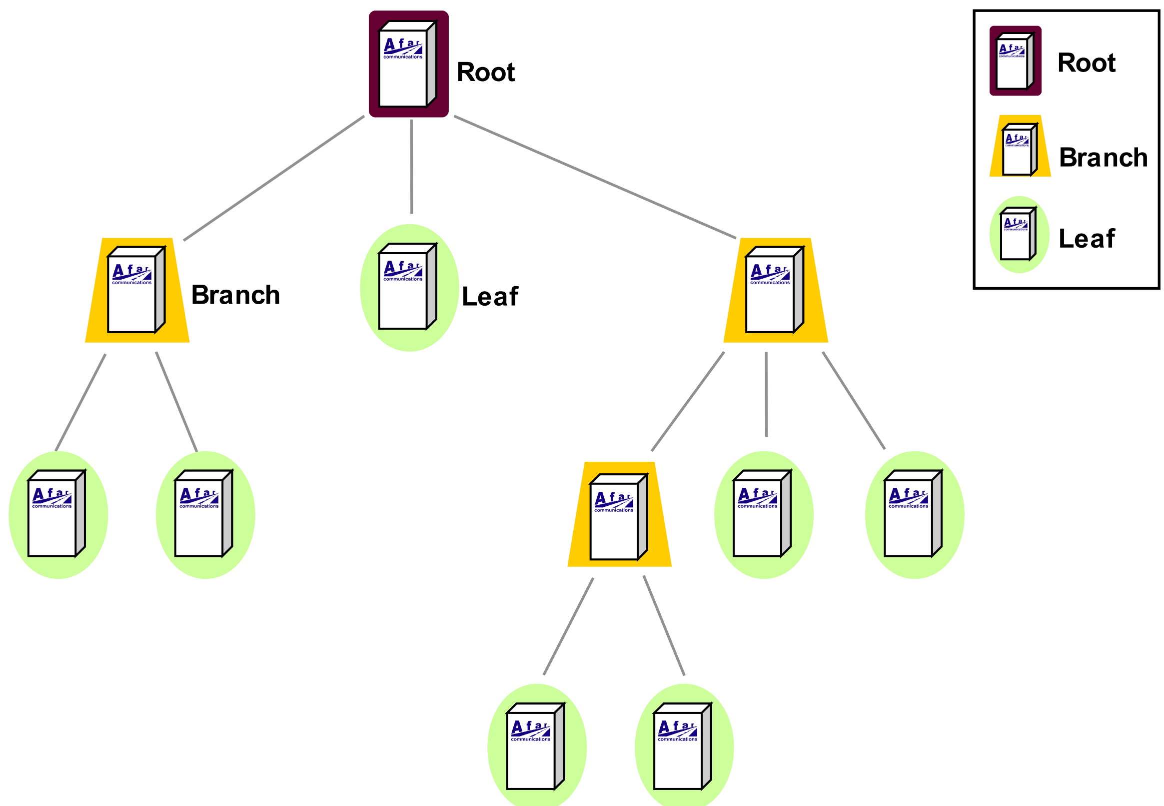


Figure 2.1: Tree Topology

A branch node has two independent RF configurations, one for the link with the parent, the other for the links with its children. Typically you set the link with the parent to use antenna A, and the link with the children to use antenna B. This allows you to deploy a directional antenna pointing at the parent node, while using an omni-directional or sectorial antenna for the links with the multiple children. This is not mandatory, you can configure a branch radio to use a single antenna.

With a large network with many branch nodes you must pay special attention to the channel assignments. One simple approach is to allocate non-overlapping channels to each "cell" (a cell consists of a parent with all of its direct children). At the parent set both the transmit and receive channel to the channel that you assigned to that cell. At the children set them to receive from the parent in that same channel (see commands **rf-1-setup** and **rf-2-setup**). Once enough distance separates cells you can start re-using overlapping channels.

The tree topology has the following features:

- There is no limit to the number of levels on the tree.
- Automatic association of new remote radios: just configure a new remote to receive on the transmit channel of the desired parent, and it will automatically associate to the network (use the "network-id" of the **node** command to prevent unauthorized radios from attaching).
- Self-learning bridging algorithm: the radios automatically learn the addresses of your equipment attached on any of the LANs and route the packets using the minimal number of hops to reach their destination.
- Self-healing network: If a parent node goes down a branch continues to operate and pass data between its children. Once the parent recovers the branch automatically reattaches to the rest of the network.

<u>Dual antenna root mode</u>: You also have the option of running the root with two antennas. This may be useful if your remotes are grouped geographically such that you can use two directional or sectorial antennas to cover each group. To run in this mode set the node type to **root-2** and use **rf-1-setup** and **rf-2-setup** to configure the RF parameters for each antenna.

<u>Tree Network throughput</u>: A branch radio allocates half of the time to communicate with its parent and the other half with its children. A root radio does not have a parent, so it divides its children into two groups communicating with one group during the first half cycle, and with the second group during the second half. Each of these two groups gets half of the total network capacity. Therefore in the tree topology the maximum throughput available at one specific node in the tree is half of the total network capacity. This is irrespective of the level in the tree, i.e., there is no further drop in throughput as you go down the various levels.

2.1.4 Linear Network

A Linear Network topology is ideal for providing communications in systems that naturally require stations deployed along a line. Some of the applications are:

- Railway wayside communications
- Pipeline communications
- Highway roadside communications
- Long links that requires multiple repeaters between the end points

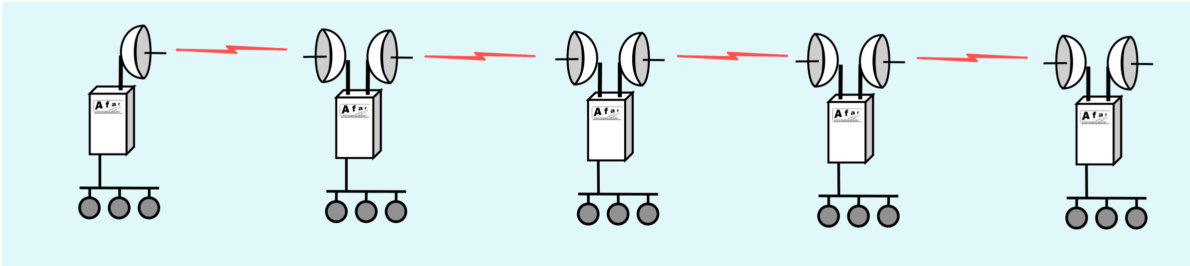


Figure 2.2 - Linear Network Topology

You can easily implement a Linear Network as a subset of the Tree topology: configure the leftmost radio as a root and all the radios in the network as a branch. Install each radio with two directional antennas pointing at their two neighbors.

2.1.5 Loop Topology

If the geographic location of the various nodes is appropriate you can deploy a “loop” network. This is similar to the Linear Network above with the addition of a link between the last node and the first. In this deployment you configure every node as a branch. The radios automatically select one of the nodes to become the root and the loop operates as a linear network with no traffic in the link to the “left” of the self-selected root, which avoids a continuous loop. If any one of the individual links goes down due to interference or obstructions, the loop reconfigures itself such that connectivity is still kept between every node.

2.2 Roaming

With the roaming option, a remote, leaf, or even a branch node, can be configured with up to six different receive channels (see command **rf-1-setup**). With this capability you can deploy **multiple access points** in a region where a group of mobile radios will move around. Mobile radios attach to the network through any of the access points and automatically switch to a new one whenever the need arises.

This capability is ideal for communications between a control center and vehicles, where the vehicles must move beyond the range of a single hub radio.

All the access points are typically connected, through a backbone network, back to a central site. This backbone network can be wired or wireless. You can use the tree topology and have each branch and root serve both as access points and backbone nodes to bring the traffic back to the central site (see figure).

The overall system supports the following features:

1. Mobile nodes automatically attach to the strongest access point.

2. As a mobile unit moves and the link to its parent fades, the mobile radio changes autonomously to attach to a stronger parent.

3. Connectivity to a central site, through a backbone network, is maintained when a mobile changes parent. Packet routing is switched over autonomously throughout the network so that packets are correctly routed immediately after the mobile radio changes the access point.

4. Using the Tree topology you can use the fixed nodes in the tree (root and branches) to provide the backbone network. Those same radios can also be the access points to the mobile leaf nodes. This approach depicted in Figure 2.3.

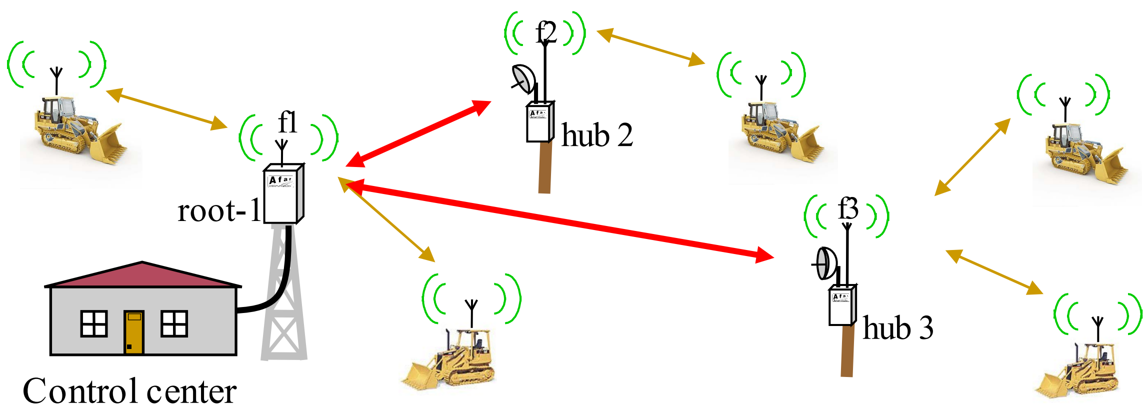


Figure 2.3 - Roaming vehicles attaching to any of three access points

Each roaming radio decides on its own when to switch to another access point. If the signal strength from the current parent drops down to a point where the link performance becomes compromised, **and** there is a stronger signal from an alternate access point, then the mobile radio drops its current link and reattaches to a stronger parent. Once it reattaches to the network, the roaming radio broadcasts its new position so that all the equipment in the network will update their routing tables accordingly. Overall the switch-over takes less than 150 ms.

Note that even branch nodes can be configured to roam. When a branch node roams and changes its access point all of its children typically move with it. When you have a network with roaming branches you may need to limit the number of access points to about six, or plan the channel assignments very carefully to avoid interference in the network once you start repeating channels assigned to each access point.

<u>Redundant hub operation:</u> In a point-to-multipoint deployment it is often desirable to deploy the hub site with two redundant radios. You can use the roaming feature to achieve this result. Configure the two hubs to different non-overlapping channels. Configure all the remotes to roam between the two hub channels. If one of the hub radios fail, or if there is interference in one of the channels, the remote radios will automatically attach to the other hub.

In this application, since you would be co-locating the two hub radios, you need to pay attention to the possibility of self-interference. Section 2.4 describes this issue and what you need to do to avoid it.

2.3 Time Division Duplex

2.3.1 Fixed and variable cycle split

The *pulsAR* radio operates in Time Division Duplex (TDD) mode meaning that the radio switches between transmit and receive over RF. In a point-to-multipoint topology this **cycle** consists of one phase used for **outbound** transmissions (from parent to children) and a separate phase for **inbound** transmissions (from the children to the parent). In the tree topology the cycle includes four phases: a branch node first communicates with its children (transmit and then receive) and then with its parent(receive and then transmit).

The radio provides two parameters that let you configure the TDD operation to best suit your application. You can select the total **cycle period** between 20 and 40 ms and you can control the **cycle split** to favor either outbound or inbound traffic. You only need to set these two parameters at the hub or root node: all the children will pick up these TDD values from their parents.

A cycle period of 20 ms (default) results in lower latencies throughout the network. However there will be more transitions between transmit and receive resulting in somewhat lower throughput capacity for the network. A cycle period of 40 ms has the opposite effect.

For small networks a cycle period of 20 ms is usually preferred. If you have a network with many nodes that are simultaneously active the 40 ms cycle will give you better performance.

The cycle split controls the percentage of time allocated for outbound traffic (from parent to children) versus inbound traffic (from children to parent). The default is an automatic mode where the parent radio allocates the split of each cycle dynamically based on the amount of traffic queued up in each direction. In a tree network each parent decides this split independent of the other parents, based on the local traffic conditions. In most deployment this setting gives you the best performance.

You can also specify a **fixed cycle split**. You have the choice of 9 different values in 10% nominal increments from 10/90 (outbound/inbound) all the way to 90/10. You need to use the fixed TDD split when you co-locate multiple radios and want to avoid self-generated interference. Refer to section 2.4 for details about synchronizing co-located radios. The fixed split may also be appropriate in applications where the data traffic is constant and with pre-determined throughput.

2.3.2 On demand bandwidth allocation

The complete TDD cycle is divided into slots of approximately 1 ms each. In automatic cycle split mode, the parent radio examines the total traffic queued up for outbound and inbound, and selects an appropriate cycle split. With fixed cycle split this step is omitted.

For the outbound traffic, the parent radio allocates the bandwidth on demand to each remote. If there is no traffic to a specific remote, the parent does not transmit any packets to that remote. When the parent has packets to multiple children, it distributes the available bandwidth evenly so that all children get equal throughput.

The parent starts every outbound transmission with a broadcast packet that includes the current cycle split as well as the slot allocation for the inbound phase. All children decode this packet and only transmit if they have been assigned one or more slots during the inbound phase.

When the children radios transmit they include a bandwidth request parameter informing the parent of how much inbound traffic they have queued up. The parent allocates slots to the children based on this information. On a given cycle, each child may be allocated zero, one, or several contiguous slots to transmit. If the aggregate requested bandwidth exceeds the network throughput the parent divides the available bandwidth fairly among the active children.

Once in a while the parent allocates a single slot to children that have remained idle to check if they now have inbound traffic. This check only takes a single inbound slot and this slot is allocated dynamically depending on current traffic load, available slots, and traffic history.

2.4 Radio co-location and interference

2.4.1 Radio co-location

As a network grows it often becomes necessary to deploy multiple radios at the same site. The reasons to co-locate radios include the following:

1. In a Point-to-Multipoint or Tree network you want to achieve 360-degree coverage around a central site, but would like to use sector antennas rather than one omni. Sector antennas have higher gain than the omni and provide shielding from interfering signals originating at different sectors. In this situation you might deploy a central site with six hub radios for example, each one feeding a sector antenna covering 60-degree sectors.

2. The number of remote radios serviced by a single hub has grown to a point where the shared bandwidth is no longer adequate. You may then add a second hub radio operating on a different channel and split the remotes between two or more hubs.

3. You want to deploy two hubs to provide redundancy at the central site.

4. You want to deploy a repeater site with two “back to back” radios.

The problem is that when you co-locate two or more radios they can become the source of self-interference, *even if they are set to non-overlapping channels*. The reason for this is explained in the following section.

2.4.2 Co-located radios self-interference

The self-interference situation is illustrated in , that shows radio A transmitting on channel f1 while a co-located radio is trying to receive on channel f2. Because the antennas are in close proximity antenna B will pick up a significant portion of the signal transmitted by radio A.

Figure 2.4 also shows a block diagram of the radio front end circuitry. It includes an RF filter to reject out-of-band signals, followed by a Low Noise Amplifier (LNA), a second RF filter, Mixer and finally the Intermediate Frequency (IF) filter. Channel selection occurs at the Intermediate Frequency (IF), where the narrow band IF filter blocks out the other channels. This means that if the interferer (radio A) is in close proximity, and is transmitting while radio B is trying to receive, it may saturate the LNA or the Mixer of radio B. This results in radio B making errors even when it is set to a different channel than radio A.

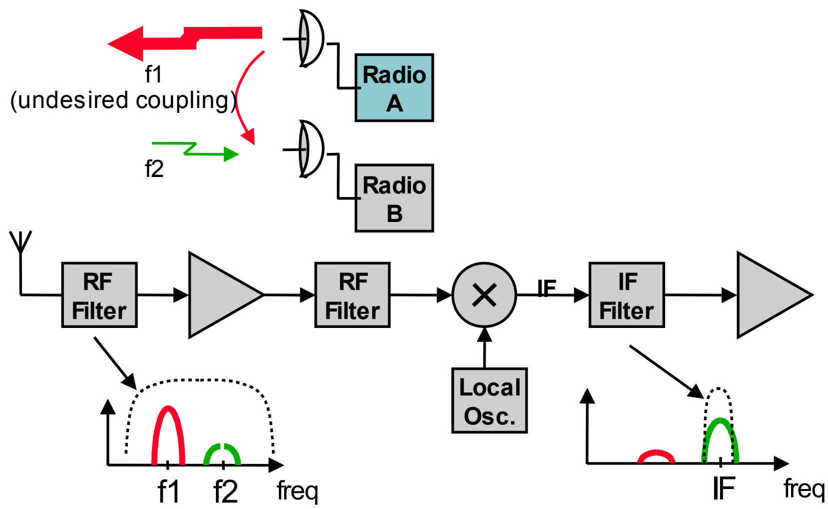


Figure 2.4 - Co-located radio interference

The traditional approaches to reduce this self-interference include:

- Separate the antennas of the two radios further apart.
- Use different antenna polarization.
- Lower the transmit power of the interfering radio.

These approaches are limited and, at most, may allow you to co-locate three of four radios. The Afar SPAN technology implements a synchronization scheme that completely eliminates this self-interference allowing you to co-locate a much larger number of radios. This is explained in the following sections.

2.4.3 SPAN Network synchronization

The *pulsAR* can be operated in a **fixed TDD** mode, where the complete cycle is divided into fixed length outbound and inbound phases. You can specify this cycle split to be 50/50 or asymmetric.

When you co-locate multiple devices you must choose a fixed split and it must be the same for all the co-located radios. The radios will then synchronize their cycle periods so that all co-located radios transmit at the same time and then receive at the same time. This avoids the situation depicted in Figure 2.4 altogether. With a synchronized site you can then deploy upwards of 24 radios at the same location.

The key to the synchronized SPAN network is the generation and distribution of the synchronization information or **heartbeat.** At any site where there is more than one co-located radio, the various radios detect each other, and automatically negotiate which should become the source of the heartbeat. If that device later is turned off or fails, another device will take its place without user intervention.

Once a heartbeat source is selected, that device multicasts into the LAN one short heartbeat packet in every cycle. All the other co-located devices periodically measure the Ethernet transit time to the source in order to cancel out any Ethernet delays through intervening switches. This process allows all the co-located radios to synchronize their cycles in a very precise fashion.

Figure 2.5 shows an example of a mixed network with multiple topologies. When the whole network is synchronized each radio runs its TDD in one of two timings, A or B, as shown in the figure. All radios at a single site run on the same cycle.

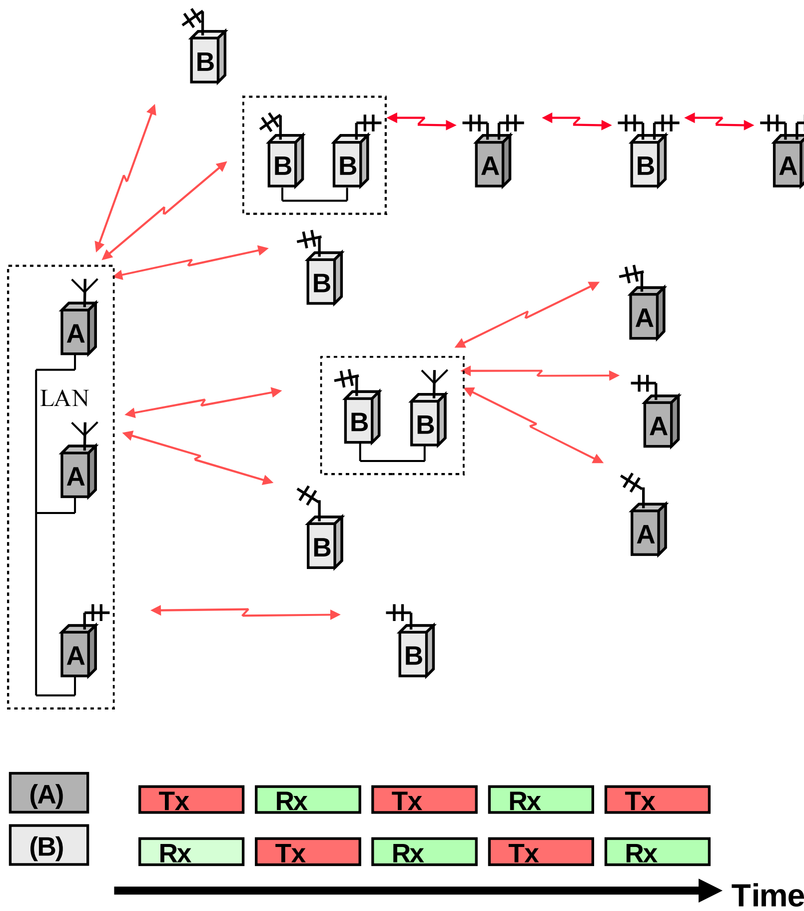


Figure 2.5 - Multiple Topology Network

The following are guidelines you need to follow to achieve a successful synchronization in a complex network:

1. At any site with multiple radios ensure that all radios are connected to the same LAN. The LAN connection between radios must run in full duplex and preferably at 100 MHz. Use the **">ether"** command to verify that the radios auto-negotiated to this setting (you can also use the same command to disable auto-negotiation and force this setting).

2. You need to use a fixed TDD cycle split throughput the network. If you are co-locating multiple hubs or roots in a point-to-multipoint or tree configurations, choose any split appropriate for the traffic in your network. You must use the same value in all co-located radios.

3. When you co-locate all hubs or all roots, you may use a cycle period of either 20 or 40 ms, but it must be the same in all co-located devices. You can mix hub and root radios at the same site, but in that case you must set the hubs cycle periods to 20 ms and the roots to 40 ms.

4. You can also co-locate a remote (or a leaf or branch) with other radios. However children nodes have their cycles synchronized to their parents. So at one given site there can only be one child node, which will become the source of the heartbeat. The other radios at that site must be hubs or roots. In this situation choose an even cycle split of 50/50.

5. Make sure that all radios have the **tdd sync-mode** set to **auto** (default).

If you follow these guidelines the radios will send the synchronization information across the network and completely avoid self-interference. Use the **“>show**” command to find which radio is the source for the heartbeat at that site and also whether there are any conflicts in the configuration.

2.4.4 Heartbeat suppression

There are situations when the multicast of heartbeat packets may not be necessary, and would put an unnecessary burden on the Ethernet. The radios detect these situations automatically and suppress the multicast of the heartbeat packets when there is no co-located device to receive them.

You may have situations where you do not wish the radios to try and synchronize to each other. For example, the Ethernet LAN may be extended with fiber or a third party wireless bridges resulting in the Afar radios assuming that they are co-located when indeed they are not. In these cases you can turn off the radio participating in the synchronization protocol by setting the **tdd sync-mode** to **off**. This is also the appropriate setting if multiple co-located radios get synchronization over RF and therefore cannot accept a heartbeat over the Ethernet. In these cases you need to avoid self-interference with the more traditional methods of increasing the separation between antennas, and/or reducing transmit power

2.4.5 Synchronization with NetCrossing Gateways

The Afar NetCrossing Gateway devices convert between a synchronous serial data stream and Ethernet packets. They can be paired with the *pulsAR* radios to establish wireless point to point serial synchronous links. When you have multiple such links and need to co-locate radios, the gateways can participate in the heartbeat negotiation and site synchronization. The gateways are equipped with a SYNC port through which they propagate the synchronization information, without having to connect the radio LANs together.

Figure 2.6 shows a network with mixed radios and gateways (NxG) and illustrates how the SPAN synchronization is achieved.

In the gateways the **tdd sync-mode** can be set to three different values: **off** (which is the default)**,** **auto**, and **master**. The figure shows the appropriate setting of each gateway. All radios should have the tdd sync-mode configured to the default **auto** setting.

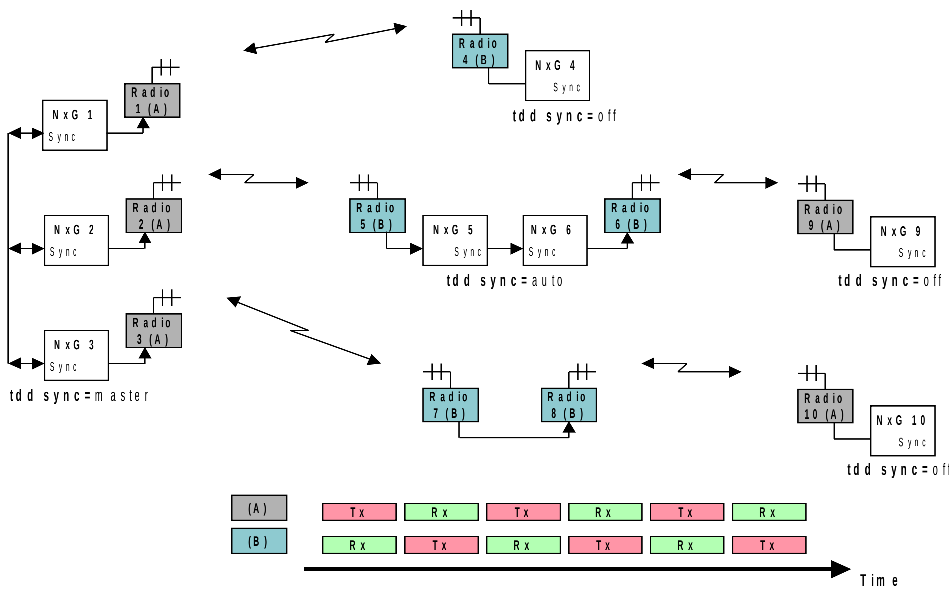


Figure 2.6– Synchronization with NetCrossing Gateways

The site on the left shows three gateways, each one connected to a respective radio. These radios are co-located and therefore their TDD cycles need to be synchronized to avoid self-interference. Since their LAN ports are not connected to each other the synchronization is achieved through the SYNC ports of the gateways. You must connect all the SYNC ports together in a daisy-chain manner, and configure the gateways tdd sync-mode to **master**. In master mode each gateway keeps a cycle timer running, synchronized to the other gateways. This synchronization is **shared**, i.e. no single gateway is the synchronization source. In fact any gateway can be added or dropped without affecting the cycle timers of the remaining gateways.

You must configure the three left radios as the "hub" for their RF links. Each of these three radios detects the presence of the respective gateway, which becomes the source of its heartbeat over the Ethernet. In this way, all three radios run their cycle times synchronized and following timeline A in the figure.

The middle site in the figure illustrates another way in which the gateways participate in the cycle synchronization. At this site radio 5 is a "remote" with its cycle synchronized to radio 2 across the RF link. Radio 5 therefore becomes the source of the heartbeat at this site. It sends heartbeat packets over the Ethernet, which synchronize the cycle timer of gateway 5. As shown in the figure you must connect gateway 5 and 6 SYNC ports together and configure their tdd sync-mode to **auto**. In this mode the gateways propagate the heartbeat between the Ethernet WAN port and the SYNC port.

Gateway 5, which receives heartbeat packets from the radio, drives the SYNC port. Gateway 6 synchronizes its cycle timer to the SYNC port and sends heartbeat packets to radio 6. The two co-located radios at this site have their cycle times synchronized, following timeline B. At this same site you could have more pairs of gateways and radios. You would connect the SYNC lines of all the gateways together and configure their tdd sync-mode to auto.

At the sites where there is a single radio and gateway you should set the gateway tdd sync-mode to **off**. Since there are no co-located radios this setting turns off the generation of heartbeat packets which are unnecessary.

2.5 Ethernet Bridging

2.5.1 Self-learning bridging

The radio operates the Ethernet port in a self-learning bridge mode. It configures the port in promiscuous mode, i.e., it examines all the Ethernet packets that are flowing in the local LAN. Since these Ethernet packets contain a **source** and **destination** address, the radio quickly learns the addresses of all the **local** stations connected to the LAN (all the source addresses of packets flowing in the LAN are local).

As a radio receives packets over RF it also learns the addresses of stations that can be reached across that RF link. For a hub radio in a PmP topology, the radio keeps track of which addresses are associated with each remote.

With this information on hand, each radio examines the destination address of every Ethernet packet in the local LAN and makes one of the following decisions:

1. If the destination address is for a local station, discard the packet.
2. If the destination address is associated with a remote radio, queue that packet to be forwarded to that remote radio. Note that for a PmP topology, the hub radio keeps multiple output queues, one per remote radio.
3. If the station address is unknown or is a broadcast send the packet to all the remote radios.

Each device has capacity to store 500 entries in its Ethernet table. Entries are erased after a certain amount of time to allow for stations to be moved between LANs and not show up in two distinct LANs. You can control this time-out with the “ethernet” command. If the table ever gets full, entries that have been least used are erased to make room for new entries.

You can examine the table of ethernet addresses and their respective nodes with the command:

```
>show ethernet
```

2.5.2 Packet priorities

As packets arrive into a radio from any port, the bridging algorithm determines if the packets need to be transmitted over RF. If so the radio queues the packets into one of several priority queues. Starting with the highest priority the packets are classified as follows:

- Vital packets: These are UDP packets with a specific destination UDP port number. This port number is part of the field programmable radio configuration (see command **>udp**).

- NetCrossing Gateways Serial packets: These are SNAP encapsulated packets containing synchronous serial data generated by the Afar NetCrossing Gateway devices.
- High-Priority: These includes network management packets for the Econsole command sessions, and also IP packets with a value in the "Type-Of-Service" indicating high priority. The radio interprets the IP TOS field per the IETF *differentiated services (DS)* definition as shown below:

0	1	2	3	4	5	6	7
Codepoint						Unused	

When the codepoint field has the value **xxx000**, the three most significant bits are interpreted as **precedence** bits. The radio gives high priority to packets with a precedence field of 6 or 7. In hexadecimal notation this translates into TOS values of E0 and C0.

- Low-priority: All other packets

When the time to transmit over RF arrives, the software always takes packets from the higher priority queues first.

2.6 Encryption

The radios have the capability of encrypting the payload data transmitted over the air. You can select the encryption algorithm between DES, Triple-DES, AES-128, and AES-256, and enter a unique key to encrypt and decrypt the data. Refer to the encryption command in section 4.4 for complete details.

Turning encryption on has the following impact on the link performance:

1. Increase in the packet size. Block encryption algorithms require the packet length to be a multiple of 8 bytes for DES or Triple-DES, 16 bytes for AES-128, and 32 bytes for AES-256. The radio uses one of those additional bytes to control the truncation of the padded field on the receive side, so there is always at least one added byte. For very long packets this padding may be negligible, but for short packets it can add significant overhead. A worst case scenario would be an ethernet packet of 64 bytes which, with AES-128 encryption will be padded to 80 bytes, and with AES-256 to 96 bytes.

2. Increase in latency. There is a small delay introduced by the additional processing to encrypt and decrypt data packets. The encrypt + decrypt time for a 100 byte packet is 0.28 ms, for a 1,000 byte packet is 0.62 ms irrespective of the algorithm. In addition to this added processing time, the increased packet size referred above also impact latency, depending on how many bytes were added to the packet and the RF transmit speed.

3 INSTALLATION AND SETUP

NOTE
Appendix E contains a quick set up diagrams showing the minimum configuration and commands necessary to put up a point-to-point link and a point to multipoint network.

WARNING
Before you turn on a radio and initiate RF transmissions we recommend that you connect the RF connector(s) to the appropriate antennas (or a load if testing in the bench). If you transmit full power into an unterminated coaxial cable connected to the antenna port the radio power amplifier may be permanently damaged.

3.1 Bench Check Out

It is recommended that an initial check be performed on the bench before a field installation.

For this bench check out you need two *pulsAR* units. Radio 1 will be configured as the hub and radio 2 will be configured as a remote. The first approach described below uses the "Ethernet Console Program" to emulate the terminal across an Ethernet connection. The second approach uses two terminals connected to the auxiliary port of the radios.

3.1.1 Using the radio Ethernet connection

In order to use the Ethernet connection you need the "Ethernet Console" (Econsole) utility provided in the CD or at the Afar website. Refer to the separate Ethernet Console User's Manual for installation instructions. Once Econsole is installed, perform the following steps.

1. Connect the "To LAN" connector of the Power Inserter Unit of radio 2 to your PC Ethernet port. If the PC Ethernet is connected to a switch go to the switch instead. The radio auto-senses and crosses the Ethernet lines if necessary.

2. Connect each radio Antenna A port (N type connector) to an appropriate 2.4 GHz band antenna using an RF coaxial cable.

3. Connect each Power Inserter Unit "To Radio" connector to the respective *pulsAR* radio using the special CAT 5 cable as defined in section 1.

4. Connect the two Power Inserter Units to a power outlet of the appropriate voltage.

5. At the PC open a DOS window and invoke the Econsole program by typing:

   > **econ**

   If you have multiple network ports in your PC the Econsole program will first ask you to select the one connected to the Afar radio. If you don't know this information just try each one in turn until you get a list of one or more Afar devices followed by the Econsole> prompt. At the prompt type:

Econsole> **connect 1** (to establish a connection to the first device on the list)

Once a connection to the radio is established, the radio outputs a prompt with the following format:

rmt-nnnnn #>

where nnnnn are the last five digits of the radio serial number. If the radio had previously been configured the prompt will be the radio **name.**

6. Set radio 2 to its factory default configuration by typing the commands:

   > **load factory**
   > **save-configuration**
   > **logout**

7. You should now see the Econsole> prompt again. Move the Ethernet cable from the radio 2 power inserter to the power inserter connected to radio 1. At the Econsole> prompt type the command:

   Econsole> **discover**

   which causes Econsole to go out and identify radio 1. Connect to this radio with the command:

   Econsole> **connect 1**

8. At the prompt from radio 1 type the commands:

   > **load factory**
   > **node type=hub**
   > **save-configuration**

9. Once radio 1 is configured as the hub it will establish a RF communication with radio 2. To verify this connection type:

   > **show**

   Check that the last lines indicates "Number of children: 1". You may also type **>show radios** to see various statistics of the link with radio 2.

10. Once the link is established you can use Econsole to further configure either of the two radios. But Econsole must first perform its discovery again to find both radios:

   > logout
   Econsole> **discover**

   Econsole should now list the two radios. Use the >**connect n** command to establish a command session to either. To logout from one radio and get the list of radios again press the key [F4].

   Section 4 describes the command language used to further modify the radio's operating parameters.

3.1.2 Using the radio auxiliary port

1. Connect each *pulsAR* Console Port to a terminal, or a PC running a terminal emulation program. Configure the terminal settings as follows:

Baud rate: 9600
Word length: 8 bits
Parity: none
Stop bits: 1

2. Connect each Power Inserter Unit to the respective *pulsAR* using a CAT 5 cable as defined in section 1.

3. Connect each radio Antenna A port (N type connector) to an appropriate 2.4 GHz band antenna using an RF coaxial cable.

4. Connect the two Power Inserter Units to a power outlet of the appropriate voltage.

5. The radios output a banner identifying the software and hardware versions and serial number, followed by the command prompt with the following format:

   rmt-nnnnn #>

   where nnnnn are the last five digits of the radio serial number. The first three letters may read **hub** or **rmt.** If the radio had previously been configured the prompt will be the radio **name.**

6. Set radio 2 to its factory default configuration by typing the command:

   > **load factory**
   > **save-configuration**

7. Configure radio 1 by typing the commands:

   > **load factory**
   > **node type=hub**
   > **save-configuration**

8. Once radio 1 is configured as the hub it will establish a RF communication with radio 2. To verify this connection type:

   > **show**

   Check that the last lines indicates "Number of children: 1". You may also type **>show radios** to see various statistics of the link with radio 2.

9. The terminal connected to each radio can be used to further modify the radio's operating parameters. Section 4 describes the command language used to perform those functions.

3.2 Field Installation

3.2.1 Mounting Bracket installation

The radio is shipped with mounting hardware designed to easily mount the unit onto a pole outdoors. You can secure the radio to poles of up to 2.5 inches (6.3 cm) in diameter.

Before taking the radio into the field, assemble the mounting hardware as follows:

1. Using the two screws provided, secure the flat aluminum plate into the recessed channel on the back of the unit. Also install the provided ground lug for connection to the earth ground as described in step 3 of the section below.
2. Thread the L shape bolt into the hole of the V shape bracket. The non-threaded segment of the bolt should be outside of the V bracket.

In order to secure the radio outdoors place the radio against a pole with the RF connectors facing up (see Figure 1.1). The back of the radio enclosure has four guiding feet that prevent it from sliding from side to side. Place the V bracket around the pole, sliding its two grooves up into the aluminum plate on the back of the radio. Once the grooves reach the stops, manually tighten the L shaped bolt so that it “bites” into the pole.

Afar also provides a different bracket for mounting the radio against a flat surface.

3.2.2 Earth Grounding

For an outdoor installation you must provide a solid ground connection between the *pulsAR* metal enclosure and the Earth ground. This will minimize possible damage due to static buildup or nearby lightning.

If you install a lightning arrestor (Afar part no SUR-0205) on the antenna connector follow these same directions but connect the grounding cable to the appropriate lug of the arrestor rather than the radio. A RF lightning arrestor is only recommended in locations where it is warranted and you use a coaxial cable of lengths exceeding 10 feet (3 m).

Each radio is shipped with a small ground lug (part no. SLU-35), and a lock washer to facilitate the installation of the ground connection.

You will require some additional supplies that are easily found at a hardware store, namely:

- AWG #6 copper grounding cable (4.1 mm diameter).
- Grounding lug, nut, bolt, lock washer (as required) for attaching the cable to the metal tower or structure.
- Anti oxidizing paste
- Outdoor cable ties (as required)

The following steps describe a procedure for a proper Earth ground connection:

1. Select an adequate grounding point on the tower or structure near the radio. This point should be below the unit and must not be inside the building. If you must drill a hole make sure it is NOT in the tower supports or cross braces. If several outdoor units are installed in the same area you may use the same grounding point.

2. Apply a thin film of anti oxidizing paste to both sides of the supplied grounding lug blade, as well as the threads of the screw used to secure the lug.

3. Install this grounding lug onto the radio enclosure with one of the two screws used to secure the mounting plate. This screw must go through (i) the lock washer, (ii) the grounding lug blade, (iii)

the radio mounting plate and finally into the enclosure, in that order. Insure that the cable connector of the grounding lug is pointing downward.

4. Prepare the grounding cable by stripping an adequate amount of insulation from both ends and apply anti oxidizing paste to the exposed copper.
5. Insert one end of the exposed cable into the radio ground lug and tighten the screw on the lug.
6. Use steel wool or sand paper to clean the grounding point on the metal tower or structure.
7. Apply a thin film of anti oxidizing paste to this grounding point surface.
8. Fasten the cable to the grounding point using a lug, bolt and nut as required.
9. If required secure the cable to the tower or structure with cable ties or clips. DO NOT bundle this grounding cable with any other cable used for data, power or RF.

Cautions

When using the anti oxidizing paste read and follow the instructions and warnings for the selected product. In addition you should note the following general guidelines:

- The paste will act as a lubricant, therefore always use lock washers.
- DO NOT apply the paste to RF and data cable connections: the anti-oxidizing paste is conductive and may degrade the performance or damage the equipment.
- DO NOT use electrical or other tape for sealing the grounding connections when using anti oxidizing paste
- DO NOT use thread-locking compound on the same screw with anti oxidizing paste.

Inspect the grounding connections on a regular basis as well as after a lightning strike. Look for cables that may have been damaged or connections that may have loosen up or oxidize over time. Replace any damaged cables or connectors and tighten any loose connections.

3.2.3 Power/Ethernet cable

Connect the outdoor cylindrical connector of the CAT5e cable to port D of the radio. The other end of this cable (with an RJ45 connector) plugs into the indoor Power Inserter Unit.

You can optionally install the Ethernet/Power Surge Suppressor module (SUP-0202) at the point where the CAT5e cable enters the building. This protects your indoor equipment against surges induced by nearby lightning on the outdoor CAT5 cable. The surge suppressor has two RJ45 connectors and a ground wire, which you must connect to an earth ground.

If you use a DC source to power the radio, make sure you do not exceed the CAT5e cable length specified in the table below. At port D the radio requires a minimum of 9.5 VDC (and a maximum of 58 VDC). With the DC voltages shown at the power inserter, the maximum cable length results in an input voltage at the radio of 9.5 VDC. The radio includes a voltage monitor which you can read with the **>show** command. This can be useful to determine the status of your battery for a battery-powered installation.

DC voltage (at power inserter)	Maximum CAT5e cable length (feet)	(meters)
10	51	16
11	153	47
12	255	78
13	358	109

3.2.4 Antenna Installation

NOTICE

The antennas for the *pulsAR* radios must be professionally installed on permanent structures for outdoor operations. The installer is responsible for ensuring that the limits imposed by the applicable regulatory agency (FCC, IC, or CE) with regard to Maximum Effective Isotropic Radiated Power (EIRP) and Maximum Permissible Exposure (MPE) are not violated. These limits are described in the following sections.

The *pulsAR* radio is typically attached to a pole (with the clamp provided) with the antenna connectors facing up. For optimum performance the radio must be mounted in close proximity to the antenna with a cable run typically under 2 meters (6 feet). Afar carries several antennas for operation at either 900 MHz or 2.4 GHz as shown below:

Band	Antenna Type	Gain	AFAR Model Number
900 MHz	Omni-directional	5 dBi	ATO-0905
	Dish Reflector	15 dBi	ATD-0915
2.4 GHz	Omni-directional	9 dBi	ATO-2409
	Dish Reflector	24 dBi	ATD-2424

Antennas at each end of the link must be mounted such that they have the same polarization, and directional antennas must be carefully oriented towards each other. The choice of polarization (horizontal vs. vertical) is, in many cases, arbitrary. However, many potentially interfering signals are polarized vertically and an excellent means of reducing their effect is to mount the system antennas for horizontal polarization. Of those antennas listed above, the directional antennas can be mounted for horizontal or vertical polarization, while the omni-directional antennas can only be mounted for vertical polarization.

Proper grounding of the antenna is important for lightning protection as well as to prevent electrical noise interference from other sources. The antenna should be mounted to a mast or tower that is well grounded to Earth. Use weatherproof connectors in all outdoor couplings. Also use the "coax-seal tape" (included with the radio) to further weatherproof outdoor connections.

The radio antenna ports come equipped with a quarter-wave short to ground which provides adequate surge protection of the RF front-end circuitry when you install the radio close to the antenna using a coaxial cable of less than 10 ft (3 m). If the coaxial cable between the radio and antenna exceeds that length you may also want to install a lightning arrestor device at the N type connector of the radio (Afar part no SUP-0205).

3.2.5 Antenna Alignment

When mounting the high gain antenna (24 dBi), the proper antenna alignment is extremely important since the beam-width of the antenna is very narrow. Once you perform a rough alignment and the link is in operation, you can use the "monitor-link" and "antenna-alignment-aid" commands. Type:

> monitor-link

in order to update, every half second, the link statistics including the RSSI level. The antenna can then be aligned so that the RSSI is maximized. In the PmP topology, the hub antenna is typically an omni and dose not need to be carefully aligned. But if you need to align a hub radio antenna for maximum signal from a particular remote use the command:

> monitor-link node=N

where N identifies the remote per the table displayed with the **show** command

Since in many applications the antenna is on a tower where it is not practical to have a terminal nearby, the *pulsAR* radio provides an "antenna alignment aid" available at the outdoor unit. This feature uses the three pin "Auxiliary port" connector to output an audio signal with a pitch proportional to the receive signal strength. AFAR provides a special cable adapter that converts the three-pin connector into a standard female audio jack. Use this cable to connect the three-pin connector to a pair of standard headphones while aligning the antenna. At a terminal session issue the command:

>aaa a-antenna (aaa is an abbreviation for "antenna-alignment-aid")

and then align the antenna until you hear the highest audio pitch. Once the antenna is aligned you may type the command:

>aaa off

to turn off the audio signal and revert the auxiliary port connector to console mode.

3.2.6 Radio Configuration

The p*ulsAR* units are shipped pre-configured with a factory default configuration. If the unit configuration has been altered, you can always reload it with the command:

> load factory

In order to deploy an RF network between two or more radios you need choose one radio to be the "hub" and configure it with the command:

> node type=hub

All other radios may be left configured with the factory configuration. As you turn them on with antennas pointing at the hub they will automatically join the network. Use the **>show** command to see the status of the radio, or the **>show radios** command for a complete list of all the radios in the network.

In most installations you may want to change several other parameters. The table below shows the most common ones and the associated commands to change them. Refer to section 4 for a complete description of each command.

Parameter	Description	Command
RF channel	You may need to change the RF channels if there is interference on the default channel (12). You can configure the RF transmit channel independently from the RF receive channel. Refer to section 3.2.7 for the procedure for choosing new channels.	rf-1-setup rf-2-setup
RF transmit power	The factory default is 18 dBm. You can configure this parameter in 1 dB increments from 0 to 27 dBm. Take care not to exceed the maximum power limits as described in sections 3.2.8 or 3.2.9	rf-1-setup rf-2-setup
Node type	In the simple point-to-point and point-to-multipoint topologies only one radio needs to be configured as the hub. In the Tree topology (and Linear Network or Loop) you will use node types of **root**, **branch**, and **leaf**. Refer to section 2 for details.	node
Network ID	The default value is 0. Change this value in all radios to a unique number to avoid unauthorized radios from joining the network.	node

3.2.7 Spectrum Analysis and channel selection

Radio operation in unlicensed bands has the potential of suffering from interference from other equipment operating in the same band. The use of directional antennas greatly reduces the potential for interference. In addition, the p*ulsAR* radio includes several features, described below, to identify and overcome sources of interference.

The radio can be commanded to perform a spectrum analysis of the ISM band and report the results in either a graphical or tabular form. The command:

>**spectrum-analysis antenna=a dwell=xx**

instructs the radio to scan the entire band, dwelling on each channel for a programmable amount of time, and record the highest signal level in that channel. This feature can be used to perform a site survey and identify the best receive channel.

Note that the RSSI value reported for each channel represents the total energy within the radio RF bandwidth centered around that channel. The radio RF bandwidth depends on the pulsAR model and can be 1.7, 4.6, or 17 MHz (see specification in appendix B). When you do a spectrum analysis any single channel sample that shows a low "noise" level, is a good candidate to select as a receive channel.

Once you identify a potential receive channel using the spectrum analysis tool, you may then use the "timing analysis" feature to confirm that the selected channel is indeed clear. The command:

>time-analysis channel=xx antenna=a dwell=xx

instructs the radio to dwell on the specified channel for the specified amount of time. After taking several samples the radio displays the signal level detected in that channel over time.

3.2.8 Output Power Limits (FCC)

The Federal Communications Commission (FCC) regulations limit the maximum Effective Isotropic Radiated Power (EIRP) for spread spectrum systems operating in the 900 MHz or the 2.4 GHz band. The tables below show the maximum allowed output power using the various antennas.

Maximum Output Power (dBm) – 900 MHz models

	Antenna Gain	
	5 dBi	**15 dBi**
AR-9010E AR-9027E	27	19

\

Maximum Output Power (dBm) – 2.4 GHz models

	Antenna Gain	
	9 dBi	**24 dBi**
AR-24010E AR-24027E AR-24110E	27	24

3.2.9 Output Power Limits (CE)

At 2.4 GHz the European Telecommunications Standards Institute (ETSI) imposes a limit of 20 dBm as the maximum Effective Isotropic Radiated Power (EIRP) for direct sequence spread spectrum systems. In addition the maximum spectral power density is limited to 10 dBm per MHz maximum EIRP.

Because of these limits only two of the radio models (AR-24027E and AR-24110E) are available for deployment in the European Community countries. When using those two models you must reduce the output power such that the EIRP of the installation does not exceed the values shown in the table below. In calculating the output power from the radio you must take into account the antenna gain, cable and connector losses.

Maximum EIRP (dBm) – 2.4 GHz models

	Maximum EIRP
AR-24027E	14
AR-24110E	20

3.2.10 Maximum Permissible Exposure (MPE) Limitations

The installer must mount all transmit antennas so as to comply with the limits for human exposure to radio frequency (RF) fields per paragraph 1.1307 of the FCC Regulations . The FCC requirements incorporate limits for Maximum Permissible Exposure (MPE) in terms of electric field strength, magnetic field strength, and power density.

Antenna installations must be engineered so that MPE is limited to f/1500 mW/ cm^2 (at 900 MHz) or 1 mW/cm^2 , (2.4 GHz) the more stringent limit for "uncontrolled environments". The table below specifies the minimum distance that must be maintained between the antenna and any areas where persons may have access, including rooftop walkways, sidewalks, as well as through windows and other RF-transparent areas behind which persons may be located.

900 MHz - Minimum Distance calculation to avoid Antenna Radiation Hazard (exposure of 0.610 mW/cm^2)

Antenna Gain (dBi):	**5**	**15**
Max. Output Power	27	19
MPE safe distance (cm)	20	20

2.4 GHz - Minimum Distance calculation to avoid Antenna Radiation Hazard (exposure of 1 mW/cm^2)

Antenna Gain (dBi):	**9**	**24**
Max. Output Power	27	24
MPE safe distance (cm)	25	25

***NOTE:** For fixed location transmitters, the minimum separation distance is 2 m, even if calculations indicate a lower MPE distance. For mobile transmitters the minimum is 20 or 25 cm (shown on the tables)

3.3 Recording the Network Configuration and Performance

Once you finish a deployment and all links in your network are operational, you should record the configuration of each radio and the performance of every RF link. Then at a later time, if you need to replace a radio, or you suspect the performance of a link has degraded, you will have easy access to the original configuration and RF performance at the time the network was deployed.

Our utility program Econsole provides an easy way to achieve this record-keeping. From a single location you can log onto every radio in the network and record the command session into a file. Below are the steps we recommend you use to keep a record of your network:

1. Start the Econsole program in a PC connected over the Ethernet to one of the radios in the network. Econsole performs a “discovery” and displays a list of all the radios it reached. Verify that every radio in the network is in that list.

2. Create a script command file as follows:

   Econsole> **edit cmd.txt**

   a new window opens where you can type any radio commands. We recommend you type the following:

   ```
   display-config
   show
   show radios
   logout
   ```

   then Save the file and close the window.

3. At the Econsole> prompt type:

   Econsole> **connect all command=cmd.txt output=my_network.txt**

   The Econsole program now will log onto each radio in turn, and perform the commands in the cmd.txt file. The output, besides going to the screen, is also being written into the file “my_network.txt”.

4. Once Econsole completes and you get its prompt (this may take some time), use any text editor to open the file "my_network.txt". The file should contain the configuration of each radio, and the RF performance (RSSI, distance, and other statistics) of each RF link.

3.4 Upgrading the Firmware.

3.4.1 Description

The operational firmware for the *pulsAR* radio is stored in Flash PROM and can be easily updated. The Flash PROM can hold multiple versions of the firmware simultaneously. The table below lists some of the "File Utility" commands used to download and manage the various files stored in Flash PROM. A more detailed explanation for each command can be found in section 4.

File Utility command summary

Command	**Description**
directory	Lists all files stored in Flash PROM
delete-file filename	Deletes the specified file from the directory
download-file path/filename	Downloads the specified file from the PC path/filename into the Flash PROM
set-default-program filename	Sets the indicated filename as the default program to run after power up
run-file filename	loads the indicated program into RAM and executes it.

New firmware versions are made available from time to time at the following page in our website:

http://www.afar.net/support.htm

The firmware files (for point-to-multipoint) are named:

pmp0x_xx.bze (binary zipped file for downloads through the Ethernet port)
pmp0x_xx.dwe (ascii file for download through the serial port, or via Telnet)

where 0x_xx is the firmware version number. The website contains instructions for transferring the files into your PC.

A new file can be downloaded into the radios in one of three ways:

1. Using the Econsole program running in a PC connected to the same physical LAN as one of the radios. This is the fastest method and allows you to download to multiple radios from the same PC.

2. Using a Telnet session from anywhere on the Internet. This requires the radio to have been pre-configured with an IP address.

3. Using a terminal emulator program (e.g. HyperTerminal) running on a PC connected through the serial port to the radio RS-232 auxiliary port. This method only allows you to download to that specific radio.

The next three sections explain in detail how to download a new file using each method.

3.4.2 Installing new firmware through the Ethernet port

This procedure assumes that the new firmware needs to be installed in all radios of a working network. The upgrade is performed from a single PC connected via Ethernet to one of the radios. Note that new firmware does not need to be compatible with the firmware currently running. You can still download incompatible firmware and restart the network from a single location.

1. If you have not done so, install the utility program Econsole in the PC. This utility program is distributed with the radios and can also be downloaded from the website. Please refer to the separate Econsole User's Manual for instructions on how to install it.

2. Make sure the file with the new firmware (file pmp0x_xx.bze) is available in the PC.

3. Start the Econsole utility by typing “econ” at a DOS command window. Econsole will send a “discovery” message and display all the radios that can be seen. Verify that all radios in the network are listed.

4. Establish a command session with one of the radios in the list with the command:

   Econsole> **connect n** (where “n” is the number of the desired radio in the radio list)

5. Once you get a command prompt from that radio type:

   >directory

   to view a list of files stored in Flash PROM as well as the available free space. Verify that the free space in flash PROM is larger than the size of the pmp0x_xx.bze file in the PC. If there is not enough space in Flash PROM delete one of the program files to make up space (use command >delete filename).

6. If the radio configuration has been password protected, you must first unlock the protection with the command:

   >**unlock enable-configuration=***password*

   (when the configuration is unlocked, the radio prompt ends with the characters ‘#>. In locked mode the prompt does not include the ‘#’ character).

7. Issue the command:

   >download *path/*pmp0x_xx.bze

   where *path/* is the directory in the PC where the pmp0x_xx.bze file is stored. The *path/* extension is not required if the file is in the same directory as the Econsole program. As the download proceeds Econsole displays a line showing the current percentage complete.

8. Once the download is complete, issue the command:

   >set-default-program pmp0x_xx

in order to make the new file the default program to run after a reset.

9. Issue the command:

   >directory

   and verify that the new file is in flash PROM, has the expected size, and is identified as the default program. Note that until you reboot the radio (below) the older version is still running.

10. Depress the "**F4**" key to log-off the session with the current radio. Econsole displays the list of all radios from the initial discovery phase. Repeat steps 4 through 9 for each of the radios until all radios have the new firmware version.

    You can also use a script file to have Econsole send the set of commands above to all radios sequentially, instead of doing this manually as explained above. Refer to the Econsole User's Manual for details.

11. Once all radios in the network have the new program in memory you must log onto each one in turn and reboot it with the command:

    >reboot

    which causes that radio to restart using the new firmware. However, if new firmware is NOT compatible with the existing one, you must choose the order of the radios that you reboot very carefully. If you have a complex network use the command **">show tree"** to see the complete topology and where the local radio is (identified by an asterisk) within the tree. Always reboot the radios that are further away (in number of hops) from your current location first, and move to the closer radios. The local radio should be the last one to reboot.

12. Once you reboot the local radio, wait a few seconds, then, at the Econsole> prompt type:

    Econsole> **discover**

    you should now see the complete list of radios and on the right hand column the current version of the firmware should be listed. Verify that all radios are running the latest version.

3.4.3 Installing new firmware using Telnet

Telnet is a protocol that allows you to conduct a remote radio command session from a local host. The radio must have been pre-configured with an IP address and be reachable, over the network, from the local host. Refer to section 5 for details on how to configure a radio IP address and initiate a Telnet session. The Telnet terminal emulation must have the capability of sending an ASCII file to the remote machine. The following description assumes you are using Hyperterminal as the local Telnet terminal emulation.

1. Verify that the new software is available in the local machine. The download software for upgrade via Telnet must have a ".dwe" extension, e.g., pmp0x_xx.dwe.

2. Initiate a Telnet session with the radio as described in section 5.

3. If the radio configuration has been password protected, you must first unlock the protection with the command:

   >**unlock enable-configuration=***password*

(when the configuration is unlocked, the radio prompt ends with the characters ‘#>. In locked mode the prompt does not include the ‘#’ character).

4. Issue the command:

   >directory

   to view a list of files stored in Flash PROM as well as the available free space. Verify that there is enough free space in flash PROM for the new file. The space required will be the size of the pmp0x_xx.dwe file divided by 2.5. If there is not enough space in Flash PROM delete one of the program files to make up space (use command >delete filename).

5. Start the download process by typing:

   >download-file destination=pmp0x_xx method=inline

   where 0x_xx file is new version of software being installed.

6. The radio will return with the following:

   “*Send the file ... if incomplete, end with a line with just a period*”

   When you get this prompt, go to “Transfer-Send Text file…” in Hyperterminal and select the file to be installed. The file must have a “.dwe” extension.

7. After the file is successfully installed issue the command:

   >directory

   to insure that the file has been loaded into memory.

8. Issue the command:

   >set-default-program pmp0x_xx

   where 0x_xx file is new version of software being installed.

9. Issue the command:

   >reboot

   to restart the radio with the new software. Close the Telnet session, wait a few seconds and open a new session with the same radio.

10. Issue the command:

    >version

    to insure the radio is running the latest version.

3.4.4 Installing new firmware using the RS-232 serial port

On occasion, it may be necessary to install new firmware using the RS-232 port. This is generally a less desirable method as the download time is much longer and you can only update the radio that is directly connected to the PC, i.e., remote updates are not possible.

The serial upgrade uses a PC with a terminal emulator. Any emulator can be used, however, it must have the facility to download a text file on demand. In the example below, the emulator used is Windows HyperTerminal.

1. Connect the *pulsAR* Auxiliary Port (3 pin circular connector) to a terminal, or a PC running a terminal emulation program. A special adapter cable is supplied by AFAR. Configure the terminal settings as follows:
   Baud rate: 9600
   Word length: 8 bits
   Parity: none
   Stop bits: 1

2. Verify that the new software is available in the PC. The download software for the serial upgrade must have a ".dwe" extension, e.g., pmp0x_xx.dwe.

3. To have the shortest download time possible, set the radio to use the highest RS-232 speed allowable on the PC. In this example, a download speed of 115200 baud will be used. Set the console speed of the radio to 115200 baud by issuing the command:

   >console-speed-bps 115200

4. Change the baud rate of the PC to match the radio. Remember that with HyperTerminal, you must disconnect the session and re-connect before the changes will take effect. Verify the PC communicates with the radio again.

5. If the radio configuration has been password protected, you must first unlock the protection with the command:

   >**unlock enable-configuration=***password*

   (when the configuration is unlocked, the radio prompt ends with the characters '#>. In locked mode the prompt does not include the '#' character).

6. Issue the command:

   >directory

   to view a list of files stored in Flash PROM as well as the available free space. Verify that there is enough free space in flash PROM for the new file. The space required will be the size of the pmp0x_xx.dwe file divided by 2.5. If there is not enough space in Flash PROM delete one of the program files to make up space (use command >delete filename).

7. Start the download process by typing:

   >download-file destination=pmp0x_xx method=inline

   where 0x_xx file is new version of software being installed.

8. The radio will return with the following:

   "*Send the file ... if incomplete, end with a line with just a period*"

   When you get this prompt, go to "Transfer-Send Text file…" in HyperTerminal and select the file to be installed. The file must have a ".dwe" extension.

9. After the file is successfully installed issue the command:

   >directory

   to insure that the file has been loaded into memory.

10. Issue the command:

    >set-default-program pmp0x_xx

    where 0x_xx file is new version of software being installed.

11. Issue the command:

    >reboot

    to restart the radio with the new software. Remember to change the PC HyperTerminal settings back to 9600 baud and disconnect/re-connect the session.

12. Issue the command:

    >version

    to insure the radio is running the latest version.

3.4.5 Feature upgrades

The *pulsAR* radio firmware includes optional features and capabilities that may have been activated at the time of purchase or you may purchase later and activate in the field. This is done via the use of the "license" command. This command requires a "key" that is specific to a particular radio serial number and capability. To obtain a feature key, you must supply the specific model number, the serial number, and the feature desired. The current optional features available for the *pulsAR* radios include the following:

Feature	Description
Tree	Allows a radio to operate as a root or branch node type in order to deploy a Tree network topology as described in section 2.1.3. Radios operating as "leaf" do not require this license.
Roaming	Allows a radio to roam between multiple access points as described in section 2.2. All radios in the network (mobile or hubs) require this license.
AES-128 Encryption	Enables the radios to use encryption in over the air transmissions using either Triple-DES and AES-128 algorithms.
AES-256 Encryption	Enables the radios to use encryption in over the air transmissions using all the algorithms supported including AES-256.

4 COMMANDS

4.1 Configuration techniques

You can establish a command session with an Afar radio in any of four different interfaces:

1. **Serial Console** through a 3-pin RS-232 port.
2. With the Afar **EConsole** program running on a PC connected to the radio Ethernet port.
3. Using **Telnet** from anywhere that can reach the radio IP address.
4. Using a **UDP/IP interface** for programming using a host computer.

Serial Console: To establish a command session on this port all you need is a terminal or PC directly connected to the radio 3-pin cylindrical connector. Afar provides an adapter cable (CBL-0403-003) to convert this connector to a DB9 female. By default this port is set as follows:

Baud rate: 9600
Word length: 8 bits
Parity: none
Stop bits: 1

This port allows you to configure and monitor only the local radio, i.e. you can not reach any of the remote radios through RF. It is often used for bench testing and for setting up device parameters prior to installation.

Econsole: This is an Afar program, available on the distribution CD or downloaded from our website, that runs on a PC Windows or a Linux platform connected to the same Ethernet LAN as the radio. With Econsole you can reach any local radios and also remote radios across multiple RF hops. However, Econsole does not cross an IP router. Refer to the separate Econsole User's Manual for instructions on its installation.

Telnet: Lets you establish a command session with a radio from anywhere on the Internet. The only requirement is that the radio must have been pre-configured with an IP address using one of the previous two interfaces (see **ip-configuration** command). Telnet is explained in more detail in section 5.

UDP/IP Interface: This is intended to allow a host computer to issue all the same text commands available through the other interfaces. Refer to the **udp-configuration** command and section 5.3 for details.

On power up the radio performs several diagnostic and calibration tests. At the end of these tests it outputs the command prompt. The default prompt has the following format:

rmt-nnnnn #>

where nnnnn are the last five digits of the radio serial number. The first three characters are an abbreviation of the **node type** in the network, which may be: hub, rmt, rt1, rt2, bra, lf. If a node "name" has been assigned to the node, the prompt will be that name.

The “help” command provides a list of all the commands available. To get more detailed help for a specific command, type “help command-name”.

The radio keeps a history of several of the previously issued commands. Those commands can be viewed by pressing the up-arrow and down-arrow keys on the keyboard. Any of those previously issued commands can then be edited and reentered by pressing the <Enter> key.

4.2 Command syntax

The command interpreter in the *pulsAR* radio is designed to accommodate both a novice as well as an expert operator. All commands and parameters have descriptive names so that they are easily remembered and their meaning is clear. In order to be descriptive however, those commands are sometimes long. As the operator becomes familiar with the command language, typing the complete words could become cumbersome. The *pulsAR* radio command interpreter recognizes any abbreviations to commands and parameter names, as long as they are unambiguous. If an ambiguous command is entered, the radio will output all possible choices.

Commands have the following generic form:

command parameter=value parameter=value

You can enter multiple commands in one line by separating them with a semi-colon. If one of the commands has a syntax error the radio executes all commands up to the one with the syntax error and discards the remaining commands.

Following is a brief list of syntax rules:

- Words (for commands, parameters, or values) can be abbreviated to a point where they are unambiguous.

- Some commands or parameters consist of compound words separated by an hyphen. With compound words, the hyphen is optional. Additionally each word in a compound word can be abbreviated separately. For example, the following are all valid abbreviations for the command “save-configuration”: “save”, “savec” s-c” “sc”.

- The parameter and value lists are context sensitive, i.e., in order to solve ambiguities the command interpreter only considers parameters valid for current command, or values valid for the current parameter.

- The arguments “parameter=value” must be entered with no blank spaces on either side of the ‘=’ sign. Those arguments (parameter/value pairs) can be listed in any order.

- Even though parameters can be listed in any order, there is a “natural” order known by the command interpreter. This allows the user to specify parameter values without having to type the parameter names. For example the command

  >**spectrum-analysis antenna=a display=table**

  can be entered as (using abbreviation rules as well):

  >**spa a t**

- Using the preceding rule, for commands that have a single argument, the “parameter name” part of the argument is always optional, i.e., you can enter:

  >*command value*

  For example the command:
  >**save-configuration destination=main**
  can be shortened to any of the following:
  >**save-configuration main**
  >**save main**
  >**save**

- Not all parameters associated with a command need to be specified. Depending on the command, when a parameter is omitted it either assumes a default value or keeps the last value assigned to that parameter.

- For all parameters that accept a numeric value, the number can be entered in decimal or hexadecimal notation. To enter a number in hexadecimal notation precede it with a 0x or 0X. All other numeric values are interpreted as decimal. Example:

  >**rf-1 receive=0x1a** (hexadecimal)

  >**rf-1 receive=14** (decimal)

The following sections describe the various commands grouped according to their functionality. A summary list of all commands are contained in Appendices A and B.

4.3 Configuration Management Commands

A **radio configuration** consists of a set of programmable parameters that define the radio operation with regard to a variety of operating modes. There are five different configurations identified as **current, main, alternate, factory** and **basic**.

The **main** and **alternate** configurations are both stored in non-volatile memory. They can be loaded into the **current** configuration with the **load** command. On power up the radio loads the **main** configuration from non-volatile memory into the current configuration.

The **current** configuration is the set of parameters currently being used and can be modified by the operator through several commands. This configuration is volatile. If the current configuration has been modified it should be saved using the **save** command. Otherwise the modifications will be lost if power is removed.

The **factory** configuration can not be modified by the operator and is used to return the radio to the factory default condition. It is useful as a starting point to create a customized configuration.

The **basic** configuration is similar to the factory configuration with the exception that a few parameters are left unchanged when you issue the **load basic** command. The parameters left unchanged are the IP and RF-1 configurations. This is useful when you are logged on to a remote unit and need to start from a known configuration. If you were to issue the **load factory** command you might lose contact with the remote unit if, for example, it changes the radio channel of the remote radio.

The access to change the radio configuration can be password protected. This password is set by the user with the **change-password** command. Once a password is set, issue the **lock** command to prevent any unauthorized changes to the configuration. Once locked, the configuration can only be modified by issuing the **unlock** command with the correct password.

When the configuration is unlocked, the radio prompt ends with the characters ‘#>’ to remind the user that the configuration is unlocked. In locked mode the prompt does not include the ‘#’ character. Once a password is set, the radio will automatically lock the configuration after 10 minutes without any commands being issued.

The configuration management commands are listed below:

change-password

enable-configuration=”ASCII string”

This command allows the user to set or change a password used to “lock” and “unlock” access to the commands that change the radio configuration. The *pulsAR* radio is shipped with no password which allows access to all commands. Once a password is set and the configuration is locked, the password is needed to unlock the access to those commands. After changing the password you should also issue the “save-configuration” command to save the new password in non-volatile memory.

Examples:

>change-password enable-configuration=bh7g8

WARNING

The p*ulsAR* radios are shipped with no password. If you set a password make sure you do not forget it. Once locked, without a password, you need to contact the factory to have the radio unlocked.

display-configuration

source= current or ***main*** or ***alternate*** or ***basic*** or ***factory***

Displays all the parameter values for the specified configuration. If the source is not specified it defaults to “current”. The figure below shows the table displayed with the factory default values:

```
--------------- TDD Radio Configuration (factory) ---------------
 Node type:    Remote              Name:     rmt-15005
 Max children: (not applicable)    Location: Not defined
 Network ID:   0                   Contact:  Not defined

 RF-SETUP    1:with parent        2:(not used)
   antenna:    A                   B
   rec-chan:   12                  25
   tr-chan:    12                  25
   tr-power:   18   dBm            18   dBm
   speed:      2.75 Mbps           2.75 Mbps

 TDD                              ETHERNET
   sync-mode:  auto                speed:               auto
   cycle:      20 ms               station-timeout:    30    sec
   split:      auto                multi-cast-timeout: 30    sec

 Time-zone:    GMT                Single-node-timeout: 900   sec
                                  Distance-max:        80    km
 IP and SNMP:
  IP Address:                Netmask:                 Gateway:
  No SNMP managers defined
```

Examples:

> **display-configuration factory**

> **disco**

load-configuration

source=main or ***alternate*** or ***basic*** or ***factory***

Loads the specified configuration into the current set of parameters controlling the radio operation. If no source is specified it defaults to the “main” configuration.

Examples:

> **load-configuration source=factory**
> **load**

lock

This command locks the access to all the commands that can alter the radio configuration. Once locked use the “unlock” command to regain access to those commands. Note that a password must be set prior to the “lock” command being issued (the radios are shipped with no password), otherwise the lock command has no effect. If a password is set, the radio automatically “locks” the configuration at the end of 10 minutes with no command activity.

save-configuration

destination=main or ***alternate***

Saves the current set of radio operating parameters into one of the two non-volatile configurations. If the destination is not specified it defaults to “main”.

Examples:

> > **save-configuration destination=alternate**
> > **save**

unlock

debug-mode="ASCII string"
enable-configuration="ASCII string"

This command unlocks the access to various commands. The **enable-configuration** password (set with the change-password command) unlocks the various commands listed in this manual that alter the radio configuration. The **debug-mode** is a factory mode used for troubleshooting by customer support.

Examples:

> **> unlock enable-configuration=bh7g8**

4.4 Major Configuration Parameters

These commands change several operating parameters of the radio that are part of the radio configuration. When entering commands with multiple parameters, if a parameter is not included, that parameter keeps its current value.

distance

maximum=10..500 (km)
units=km or ***miles***

Sets the limit for the maximum distance of any RF link in this network. You only need to set this maximum distance at the root or hub node. All other nodes will automatically configure the maximum distance to that of the parent node.

The units you choose (km or miles) will be used in other displays when reporting the measured distances.

In general you should leave the maximum distance set to the default value of 80 km (50 miles). But if you are deploying a network where one or more links exceed this distance you must change this parameter to a value that is equal to or greater than the maximum link distance.

Increasing the maximum distance results in a slight decrease of the network capacity.

If you enter a value greater than 255 km it will be rounded to 300, 400 or 500 km.

Examples:

> **> distance 100 km**

> **> distance units=miles**

encryption

mode=off or ***des-56*** or ***3-des-112*** or ***aes-128*** or ***aes-256***

Selects the encryption algorithm applied to all user data packets transmitted over-the-air. All units support the **des-56** mode. The other modes may be blocked, you can use the “>help encryption” command to find which modes are available in your unit.

When using encryption you must set all units in the network to the same mode and enter the same key. The number at the end of each mode name is the length, in bits, of the key used in that encryption mode.

key=XXXX-XXXX-XXXX-XXXX-…
key-phrase=<string>

You can enter the key using hexadecimal digits in groups of 4 separated by optional dashes. The table below shows the number of hexadecimal digits required for each mode.

Table 4.1: Encryption key lengths

	DES-56	3-DES-112	AES-128	AES-256
Key length (bits)	56	112	128	256
Hexadecimal digits	16	32	32	64

In the DES modes the least significant bit of each key byte is a parity bit. Therefore each byte contributes only 7 bits to the key length. You do not need to enter the key with the correct (odd) parity, the software will enforce that and echo back the key with the correct parity.

The **key-phrase** parameter provides an alternate way for entering a key. You can enter any ascii string of up to 80 characters and the radio will generate a pseudo-random key of the appropriate length. The key phrase may have spaces but you need to put it in quotes. Note that the key-phrase is not stored in the radio configuration, only the generated key.

Example:

> encryption aes128 key-phrase=”Acronym For Afar Radios”

ethernet

speed=auto-10 or ***10hdx*** or ***10fdx*** or ***100hdx*** or ***100fdx*** or ***auto*** or ***off***

Sets the ethernet port speed to a combination of 10 or 100 Mbps, half or full duplex, or auto negotiate.

In installations requiring a very long outdoor CAT5 cable, operation at 100 Mbps may become unreliable. For this reason the **auto-10** setting forces the speed to 10Mbps but negotiates the half vs full duplex setting. The **auto** setting (default) negotiates both the speed and duplex to the fastest configuration supported by the other device on the Ethernet. With either of the **auto** settings the radio also detects and crosses over the Tx and Rx signal pairs, if necessary. This automatic cross-over feature is disabled in the non-auto settings.

You can also turn **off** the ethernet port, but only if your command session is over the console port, or remotely over an RF link. This can be useful for test purposes if you suspect that you created a loop in the network and want to shut down this port without turning off the radio.

timeout-sec=5..10000

Sets the time the radio will retain Ethernet addresses obtained from the network.

multi-cast-timeout-sec=5..10000

Sets the time the radio will retain Ethernet multi-cast addresses obtained from the network. This can not be set to a value below the station-timeout.

Examples:

> **ethernet speed=10fdx timeout=100**

node

type=hub or ***remote*** or ***root-1*** or ***root-2*** or ***branch*** or ***leaf***

For a point-to-point network configure one of the two radios as the **hub** and the other as the **remote**. At the hub also set the **max-children** parameter to 1, which optimizes the network for point-to-point.

For a point-to-multipoint network configure the central radio as the **hub** and all other radios as **remote**. In a fixed installation you would typically deploy the remote radios with directional antennas pointing at the hub radio.

In a tree network configure the central radio as the **root**. Use **root-1 i**f you have a single antenna at the root. You may also deploy a root with two antennas on ports A and B in which case use **root-2**.

In a tree network all other nodes must be configured as either **branch** or **leaf**. A branch node will attempt to connect to a parent (which can be the root or another branch) using the rf-1 configuration. It will also be acting as a parent and serve as an access point using the rf-2 configuration.

A **leaf** node will attach to the parent (root or branch) using the rf-1 configuration.

When you attempt to configure a node to be a branch or a root the radio may indicate that it is not authorized to operate in that mode. In that case contact Afar to purchase a key to operate the radio in the tree topology.

max-children=1..32

At the hub, root or branch nodes this value specifies the maximum number of children that will be allowed to join the network through this access point. Once the radio has the maximum children specified it stops allocating a slot for new nodes to join the network. This improves the inbound throughput slightly, specially if the number of children is small. It also prevents an unauthorized radio to join the network. In a point-to-point link make sure you set this parameter to 1.

name="ASCII string"

Gives the node a meaningful name for further reference. This name will be used as the command prompt. It is also used to identify the node in a variety of commands and displays. The name field can be up to 23 characters with no spaces. If spaces are desired, you may include the whole name in quotation marks. In some displays the name is truncated to 10 characters.

network-id=0..65,535

You must set all the radios that are part of the same network with the same network-id, otherwise they will not be allowed to join the network. The default value is zero. We recommend that you set the network id to a unique number that you keep private to prevent an unauthorized radio to join your network.

To keep the network-id private its value is only displayed if the configuration is unlocked.

location="ASCII string"

Optional parameter to define the location of the node. This field is displayed in the "Display-configuration" output and also reported through SNMP. This field is used for information only. The location string can be up to 25 characters with no spaces. If spaces are desired, you may include the whole string in quotation marks.

contact="ASCII string"

Optional parameter to define the contact for maintenance purposes. This field is displayed in the "Display-configuration" output and also reported through SNMP. This field is used for information only. The contact string can be up to 25 characters with no spaces. If spaces are desired, you may include the whole string in quotation marks.

Examples:

>node name=bank location="wall street" contact=964-5848

rf-1-setup
rf-2-setup

antenna=a or ***b***
receive-channel=nn,nn,nn….
transmit-channel=nn
power-dbm=0..27 or 0..26 *(see table 4.3)*
speed-mbps=<rf-speed>

There are two RF configurations, 1 and 2, which take the same parameters. In most deployment you only need to deal with RF configuration 1. The only deployments that make use of RF configuration 2 are for Tree/Mesh networks, node types **root-2** and **branch** as shown in the table below. You can use the ">display-configuration" command to find which RF configurations are being used.

Table 4.2 – Use of rf-1 and rf-2 configurations

Topology	Node type	rf-1	rf-2
Point-to-Multipoint	hub	Link with children	Not used
	remote	Link with parent	Not used
Tree	root-1	Link with children	Not used
	root-2	Link with children	Link with children
	branch	Link with parent	Link with children
	leaf	Link with parent	Not used

antenna: In most topologies use antenna A for the RF configuration 1, and antenna B for the RF configuration 2. This is not mandatory, there are situations when you may want to override this default.

receive-channel: For the link with the parent this value must match the transmit channel of the desired parent. If you have the roaming option enabled you can specify up to six receive channels for the rf-1 configuration (separate values with commas but no spaces). These channels should match the transmit channels of separate access points in the area (hub, root or branch). The radio will then attach to the parent with the strongest signal and change parent automatically when the signal becomes too weak. See Table 4.3 below for the valid channel numbers.

transmit-channel: This is only applicable at the parent nodes for the links with their children. At the child nodes, the transmit channel is configured automatically when the node attaches to the parent (it will be set to match the receive channel of the parent). See table 4.3 below for the valid channel numbers.

power-dbm: This is the transmit power fed into the antenna. The default value is 18 dBm which is adequate in most situations. If you do not have enough link margin or there is interference in your channel you may want to increase the power up to the maximum value. If your links are very short and you have plenty of signal you can reduce the transmit power in order to re-use the same channel in other links in the area.

speed-mbps: This is only applicable at the parent nodes for the links with their children. At the child nodes the speed is set automatically to match that of the parent. The default value is always the highest speed supported by your specific model (see table 4.3 below). The lower speeds may be appropriate for very long links where the receive signal strength is too weak and you need a little more link margin. We suggest that in those cases you first increase the transmit power and only then start reducing the speed.

Example:

> rf1 ant=a rec=15 tra=15 po=27 sp=0.5

> rf1 rec=6,13,18,24

Table 4.3– RF parameters ranges

	AR-9010E	AR-9027E	AR-24010E	AR-24027E	AR-24110E
Channel ranges	3...27	5...25	1...40	2...39	5...35
Rf-speeds (mbps)	0.10 0.20 0.55 1.10	0.25 0.50 1.375 2.750	0.10 0.20 0.55 1.10	0.25 0.50 1.375 2.750	1.0 2.0 5.5 11.0
Tx power range	0..26	0..26	0..27	0..27	0..27

single-node-reboot

timeout-sec=0,15..60000

After power up, a radio attempts to get an RF link with one or more radios. If a radio fails to get a link up (or drops all existing links), it will perform a complete reset after the timeout specified in this command. A value of zero is allowed and it turns this feature off.

This feature is useful if you issue a command to a distant radio (over an existing RF link) and the link drops as a consequence of the command. If that radio now has no other links up it waits for the "single-node-reboot" and then perform a reset. As a result, the radio reverts to the saved configuration, allowing it to reestablish the original link.

Examples:

> snr 60

time-division-duplex

sync-mode=off or ***auto***

This parameter selects whether this radio participates in the negotiation of the heartbeat synchronization to select a single source for the heartbeat. The default **auto** mode is recommended for most applications.

The **off** mode may be useful in situations where there is a variable and significant delay in the local Ethernet connecting the several co-located radios. In that case the radios may not be able to establish synchronization and you may get better results turning off the heartbeat protocol.

See section 2.4.3 for a detailed explanation of the synchronization between co-located radios.

cycle-period-ms= 20 or ***40***

A cycle period of 20 ms (default) results in lower latencies throughout the network. However there will be more transitions between transmit and receive resulting in somewhat lower throughput capacity for the network. A cycle period of 40 ms has the opposite effect.

For small networks a cycle period of 20 ms is usually preferred. If you have a network with many nodes that are simultaneously active the 40 ms cycle will give you better performance.

The cycle period only needs to be set at the hub or root nodes. All the children will pick up the cycle period from their parents.

split-outbound-percent=auto or 10 or 20 or 30 or 40 or 50 or 60 or 70 or 80 or 90

This parameter is relevant at the hub or root nodes only. It specifies the percentage of the total cycle period dedicated to RF outbound transmissions (from parent to children). The remaining time is dedicated to inbound traffic (from children to parent). You only need to specify this parameter at the root or the network hub. For all the other nodes, as they join the network they take the split information from their parent.

In **auto** mode a parent radio dynamically assigns a split based on the current traffic load in each direction. This split may be different from cycle to cycle and different at each branch on a tree.

Select fixed splits if you co-locate multiple radios and need to avoid self-interference. You may also choose a fixed split if your traffic is constant and consistently favors either outbound or inbound. In all other cases select the **auto** mode. See section 2.3.1 for a more detailed explanation of fixed versus auto splits.

At low RF speeds with low cycle period values the radio will not allow you to select some of the more asymmetric splits as they would result in packets that have too few bytes.

Example:

> tdd sync=off cycle=40 split=70

4.5 Internet Protocol (IP) Management Commands

The IP Management commands configure the radio IP protocol parameters which allow the radio to be monitored and configured through Telnet and SNMP. Refer to section 5 for a more detailed explanation on those two applications.

ip-configuration

address=<ip address>
netmask=<string>
gateway=<ip address>
dhcp-client=yes or ***no***

This command configures the radio IP address, netmask and gateway. The IP configuration is optional and the radios are shipped with these parameters left blank. Once the IP configuration has been initialized, the radios will reply to “ping” packets. The IP configuration is also required in order to use the “ping”, “snmp” and “telnet” features.

Alternatively you can enable the **dhcp-client** function. In that case the radio will attempt to configure its IP address parameters from a DHPC server in the network.

Since the two radios in a link are bridged together they are in the same “internet network”.

Example:

> **ipconfig add=207.154.90.81 netmask=255.255.255.0 gateway=207.154.90.2**

ping

destination=<string>
count=0..500
size-bytes=32..1400

This command causes the radio to "ping" the destination address and display the results. The "ping" packet consists of an ICMP packet with a length specified by the "size-bytes" parameter. The destination is any valid IP address. When the destination host receives the packet it generates a reply of the same size. Upon receiving the reply the radio displays the round trip delay. This process is repeated until the number of replies reaches the value specified by the "count" parameter (default to 4). A count of zero leaves ping running indefinitely until stopped by the user.

Example:

> **ping 207.154.90.81 count=10 size=100**

snmp

The radio runs an SNMP agent which allows up to four IP addresses to be specified as valid SNMP managers. This command configures those IP addresses and the type of access allowed. You can issue the command up to four times to specify each separate IP address manager. The radios are shipped with all entries blank. While no entries are specified, the unit accepts SNMP "get" requests from any IP address with the "public" community. Once one or more entries are specified, the radio only responds to requests from the specific IP addresses listed. This list of authorized managers is also used for validating Telnet requests.

Refer to section 5 for an overview of Network Management using SNMP and Telnet.

manager=<ip address>

Specifies one valid IP address where the SNMP manager or Telnet session will run.

community=<string>

Any string of up to 9 characters. For SNMP requests the "community" field in the request packet from this IP address must match this parameter. For a Telnet session the username entered when initiating the session from this IP address must match this string. If this parameter is not specified it defaults to "public". Note that you must always enter the "manager" IP address in the same command line that sets the "community" value.

access=g or ***gs*** or ***gst*** or ***gt***

SNMP access type authorized for this IP manager. Specify as any combination of three letters: g (get), s (set) and t(trap). If this parameter is not specified it defaults to "get". Note that you must always enter the "manager" IP address in the same command line that sets the "access" value.

authentication-traps=0 or 1

Specifies whether an "authentication trap" should be generated if a SNMP request is received that can not be honored (due to invalid IP address, community or access fields). When enabled, all IP managers that have "trap" access will receive this trap.

delete=1..4

Allows deleting one entry in the SNMP table. The number 1..4 refer to the entry number as listed in the "display configuration" report.

Example:

> snmp manager=207.154.90.81 com=support access=gst

udp-configuration

console=on or ***off***
vital-port-1=1..0xFFFF
vital-port-2=1..0xFFFF
command-port=1..0xFFFF
max-response-bytes=400..65521
socket-mode=1 or ***2***
peer-address=<ip address>
peer-command-port=1..0xFFFF

The **console** parameter turns **on** or **off** the radio UDP interface. The factory default is off. You may turn it on for either of the following purposes:

1. To send and receive **vital packets** which the radio classifies as the highest priority (see section 2.5.2).
2. Send radio configuration text commands encapsulated in UDP/IP packets. This is useful when you want to configure the radio from a program running on an external computer

The **vital-port-1** and **vital-port-2** specify two different UDP port numbers. The radio examines the "source" and "destination" ports of any UDP encapsulated packets that the radio receives and queues for transmission over RF. If any of those two values match the vital-port-1 or vital-port-2, the packet is classified as **vital priority** and is transmitted ahead of all other packets.

All the remaining parameters are used for the purposes of issuing radio commands using UDP encapsulated packets. The formats of these UDP packets and radio replies are described in detail in section 5.3.

The **command-port** parameter is the UDP port number used by the radio to receive commands.

The **max-response-bytes** parameter limits the length of the response packets generated by the radio. If the response is longer than this value it gets truncated.

The **socket-mode=1** (default) is intended for applications where the controlling program allocates a single socket for packets in both directions, while **socket-mode=2** is used when the program must create separate sockets for sending to the radio and receiving from the radio.

In both modes the radio listens for UDP packets addressed to the specified **command-port** number. In **socket-mode 1**, if you do not specify a **peer-address** and a **peer-command-port** the radio accepts packets from any IP address and port and sends the responses to the same IP address and port from which the command was received. If you specify a **peer-address** and/or a **peer-command-port** the incoming packets must match these parameters, otherwise the packets will be ignored.

In **socket-mode 2**, the radio sends the UDP command replies to the IP address specified by the **peer-address** parameter and sets the destination UDP port to the value specified by the **peer-command-port** parameter. Additionally the IP address on incoming packets must match the **peer-address** parameter.

4.6 Installation and Link Monitoring Commands

These commands are useful as installation aids and also for monitoring link statistics after the link is established.

antenna-alignment-aid

mode=off or ***a-antenna*** or ***b-antenna***

With the mode other than **off**, the radio outputs, through the auxiliary port, an audio signal with a pitch proportional to the Receive Signal Strength (RSS) level of packets received on the specified antenna. AFAR provides a special cable adapter that converts the three-pin auxiliary port connector into a standard female audio jack. Use this cable to connect the auxiliary port to a pair of standard headphones while aligning the antenna.

While the antenna alignment is on the RS-232 console output is not available. When the antenna alignment output is set to **off** the auxiliary port output reverts to RS-232 console.

The antenna alignment output setting can also be saved as part of the radio configuration. This is useful to take a pre-configured radio to an installation site with no need to turn the antenna alignment ON (through a terminal) after power up.

Example:

>aaa a-antenna

>aaa off

monitor-flow

This command continuously displays the current and peak data rates to and from all the radios that have a direct link with this one. Press the [space bar] to terminate the command.

monitor-link

node=0,1, 4..N
clear=0 or 1

This command continuously displays link statistics including the RSSI at both ends of the link, link distance, percent of packets lost, and the elapsed time since this link has been up. You must specify a valid **node** number from the list displayed by the **show links** command (if this radio is involved in only one link you do not need to enter the node number). At a parent node you may specify the node as 0 to monitor all links simultaneously. Press the [space bar] to terminate the command.

The “clear=1” parameter clears the percent of dropped packets statistic. You can also clear that statistic by pressing the “zero” key while the command is running.

Examples:

>monitor-link node=4 clear=1

monitor-roaming

If a radio is configured to roam between multiple hubs, this command shows which hubs are currently within range, and the Receive Signal Strength (RSSI) from each hub. The report also identifies the current hub that this radio is attached to. This information is refreshed once per second. Press the [space bar] to terminate the command.

show-table

table=status or ***links*** or ***tree*** or ***radios*** or ***ethernet*** or ***ip-stack*** or ***econsole*** or ***properties*** or ***sync-delays***
format=counts or ***times***

This command displays various tables in different formats as described below:

status table

This contains miscellaneous information including system start and run times, unit temperature, input DC voltage, and RF link status. If appropriate it also displays any applicable warnings regarding the current configuration or operation.

links table

This table displays various statistics for all the RF links with adjacent radios. For a leaf or remote radio there is only one entry which is the link to the parent. For a parent radio there may be multiple entries. The entry with an ID of 1 is always the link to the parent. The table shows the link distance in either miles of km. You can use the “distance” command to change the units.

If this radio is enabled for roaming and is set to receive in more than one channel, then this report also includes the “Roaming Table”. This table includes a line for each receive channel, the Hub Serial Number of a hub transmitting in that channel, the RSSI and the time elapsed (in seconds) since that RSSI was measured.

```
ROAMING TABLE:      Rx       Hub               Time
                   chan    Ser.N    RSSI   elapsed
                   ----   -------   ----   -------
                    12      16322    -73      1.0
                    25      16300    -65      0.4
   current chan ->  32      15005    -53      0.0
                    37
```

```
DIRECT LINKS:           Rmt           Rmt   My     % Dropped
 # Ant  Name    Ser.N  RSSI    km   TxPwr RSSI   Now  Ever    Uptime
 -- - --------- -----  ----  -----  ----- ----   ---  ----  ---------
  1 A bra-15005 15005   -61     0     18   -53     0   0.0  000:58:40
```

tree table

In response to this command the radio broadcasts a discovery packet to obtain information from all the radios in the network including radios that may be several hops away. It then displays various statistics for all the links. The first column indicates in an indented fashion the "level" of each radio in the tree, which corresponds to the number of hops away from the root (or hub). For each radio that is a parent the report displays the entries of all its children before moving to another node at the same level. You can find the parent of any node by going up the table to the first entry with one level lower.

```
COMPLETE TREE NETWORK:
                                            /----- Parent Link -----\
 Level  Type  #   Name      IP address        km  RSSI  %   Uptime
 ------ ---- -- --------- ---------------   ----- ---- --  ---------
 0       RT1  0 rt1-16322 207.154.90.108
  1      bra  4 bra-16300 207.154.90.161      0   -71  0  000:56:33
   2      lf  4 rmt-16323                     0   -71  0  001:05:25
* 1      bra  6 bra-15005 207.154.90.163      0   -76  0  000:58:20
   2      lf  4  lf-17001                     0   -53  0  000:56:33
```

radios table

This command displays both the **links table** and the **tree table** described above.

ethernet-stations table

This table can be displayed in two formats, "counts" (default) and "times".

>show ethernet

```
                                                  --Discard--       --Forward--
 #        MAC address   IP address    Radio     from      to      from      to
--  -----------------  --------------  -----    -----    -----    -----    -----
 0  ff-ff-ff-ff-ff-ff                  Local       0        0        0      919
 1  00-0d-94-00-3a-9d                    me        0        0      388      361
 2- 01-0d-94-00-00-01                    me        0        0        0        0
 3  00-a0-cc-66-70-8e  207.154.90.161    4         0        0   197246    99568
 4  00-a0-cc-d7-06-76  207.154.90.173   Hub        0        0    99578   197133
 5  00-a0-cc-d6-fd-50                    6         0        0      122      148
 6  00-a0-cc-d7-0b-0d  207.154.90.204    5         0        0      180        0
 7  00-a0-cc-d7-0b-14                   Hub        0        0      118        0
 8  00-0d-94-00-42-69                    4         0        0        1        0
```

>show ethernet times

#	MAC address	IP address	Radio	MC	Time added	Idle	VLAN
0	ff-ff-ff-ff-ff-ff		Local		11-Jan 22:57:57		N/A
1	00-0d-94-00-3a-9d		me	X	11-Jan 22:57:57		N/A
2-	01-0d-94-00-00-01		me		11-Jan 22:57:57	5490.86	N/A
3	00-a0-cc-66-70-8e	207.154.90.161	4		11-Jan 23:30:48		N/A
4	00-a0-cc-d7-06-76	207.154.90.173	Hub		11-Jan 23:32:32		N/A
5	00-a0-cc-d6-fd-50		6		12-Jan 00:28:22		N/A
6	00-a0-cc-d7-0b-0d	207.154.90.204	5		11-Jan 23:30:56	20.23	N/A
7	00-a0-cc-d7-0b-14		Hub		11-Jan 23:31:14	14.96	N/A
8	00-0d-94-00-42-69		4		12-Jan 00:29:06	21.64	N/A

Both formats list all the ethernet stations attached to either this radio or other radios that have a direct link to this one. The tables list the MAC (Ethernet) address of the station, and, if known, the IP address.

The first row in the table tracks broadcast traffic while the second entry is always the address of the radio itself. The Radio column shows the radio where that station is physically attached. It may have a number 4 through N which identify one of the children radios as shown in the **show links** table. Or it may say: "**Local"** to indicate stations connected to the local Ethernet, "**me"** to identify this radio, **"Hub"** for the parent radio, and **"Bcast"** for addresses that are in an unknown segment (this radio broadcasts packets to these addresses through all ports).

The "counts" format shows the cumulative number of ethernet packets that have been seen with that MAC addresses in the source ("from") or the destination ("to") fields. The radios operate the Ethernet port in promiscuous mode and therefore look at all the packets in the Local Area Network. The radios discard the packets that are known to be local, but forward all other packets to remote radios. These are accounted separately in the report.

The "times" format indicates whether that entry is for a "multicast" (MC) address, shows the time when the station was added to the table, and how long since that address has been seen. When the "idle" time exceeds the time specified by the "ethernet" command, that entry is deleted from the table.

econsole table

The unit broadcasts an e-console discovery packet on both its ports: Ethernet and RF, and then reports all the replies. These include both gateways and radios that can be reached on either port.

properties

Displays the properties of the radio hardware including the hardware version, clocks speeds, CPU version, and RF characteristics.

sync-delays

Valid only at a radio that becomes the source of the heartbeat at a site with co-located radios (see section 2.4). Use the command >**show status** to identifies the radio that is currently the source of the heartbeat. This table displays the measured transit times, over the local Ethernet, to each of the co-located radios.

spectrum-analysis

antenna=a or ***b***
display=graph or ***table***
dwell-time-ms=1..1000

This command switches the radio to receive mode on the designated antenna (defaults to **a**) and performs a scan of all the channels in the band, dwelling on each channel for the specified amount of time (defaults to 100 milliseconds). While on each channel it measures the RSSI for that channel and stores its peak value. It then displays the data collected in a graphical or table formats (defaults to **graph**).

Note that the RSSI value reported for each channel represents the total energy present in the radio bandwidth centered around that channel (see appendix B for the RF bandwidth of each model). Since adjacent channels "overlap" each other, a narrow band transmitter will show up in this spectrum analysis as a lobe with energy present in several adjacent channels. Conversely, you do not need to find a wide region in the spectrum analysis report to select a quiet channel, i.e., any single channel sample that shows a low "noise" level, is a good candidate to select as a receive channel.

Performing this function causes all RF links with this radio to drop momentarily. Once the scan is complete the links will be restored. If you invoke this command remotely through an RF link the radio waits at the end of the spectrum scan until the RF link is restored and then sends the report to your terminal.

Wen you issue this command at a child radio specifying the antenna that receives from the parent, you should see the transmission from the parent. However, if you do this at a parent you will not see the transmissions from its children. This is because children only transmit over RF if they are polled by a parent and when the parent is performing the spectrum analysis it stops all RF polls of its children.

Examples:

>spectrum-analysis antenna=b

>spa

time-analysis

channel=0..50
antenna=a or ***b***
display=graph or table
dwell-time-ms=1, 2, 5, 10, 20, 50, 100, 200, 500

This command switches the receiver to the specified antenna (defaults to A) and then measures the RSSI for a **single** channel over a period of time. Each "sample" consists of the maximum RSSI measured during the dwell time specified (defaults to 20 milliseconds). After collecting 60 samples the RSSI values are displayed graphically or numerically (defaults to "graph").

Example:

>time-analysis antenna=b

>tia ant=a dis=t dwell=500

4.7 File Utilities

The *pulsAR* radio maintains a file system that allows multiple programs to be stored in either non-volatile flash PROM or volatile RAM. New programs can be downloaded into the *pulsAR* radio memory through the auxiliary port, through the Ethernet port, or to a remote radio across the RF link.

One of the programs in flash PROM is designated as the default program to run after reboot. On power up that program is copied from PROM into RAM and the code runs out of RAM.

Both sections of memory (non-volatile flash PROM and volatile RAM) are segregated into two "directories". The non-volatile flash PROM is called "flash" signifying the flash PROM and the volatile RAM is called "tmp" signifying the temporary status of the program. Use the "directory" command to view the programs loaded and whether they are in non-volatile or volatile memory.

Any program can be invoked with the command "run" without making it the default file. This is useful when upgrading the software over an RF link as a way to ensure that the new code is working correctly before making it the default.

console-speed-bps

baud-rate-bps=9600 or ***19200*** or ***38400*** or ***57600*** or ***115200***

Sets the Auxiliary port of the radio to the specified baud rate. This setting is not saved in the radio configuration, the auxiliary port always reverts to 9600 baud on power up.

This command is useful to speed up the download process over the auxiliary port. Before issuing the download command, use this command to change the radio console speed to the highest baud rate supported by the PC. Then change the terminal settings to match the radio speed. Issue the download command described below and initiate the transfer at the terminal.

Examples:

>console-speed-bps baud-rate-bps=115200

copy-file

source=filename
destination=filename

Copies the source-file into the destination-file. If the memory location is not defined (flash or tmp), the command assumes the flash directory.

Examples:

>copy-file tmp/pmp03_25 pmp03_25

delete-file

filename=filename

Deletes the specified file from RAM or Flash PROM. If the memory location is not defined (flash or tmp), the command assumes the flash directory.

Examples:

>delete pmp03_25

directory

format=short or ***full***

Lists all the files currently stored in flash PROM and RAM, their size, the sectors occupied and the MD5 checksum (full version). It also indicates which of the files is the default program. Files stored in flash PROM have the flash/ prefix. Files stored in RAM have the tmp/ prefix.

Examples:

>dir

download-file

source=path/filename
destination=filename
method=inline or ***binary***

Downloads a program file from a PC to the Radio.

To download a file through the Ethernet port or across RF links you need to be running the Econsole program on a PC attached to a radio through the Ethernet port. In this case the program file must be in binary zipped format (with extension **.bze**). The *path/* in the source parameter is the PC directory where the file resides. The program file is transferred to the radio and is stored in memory under the name specified by the destination parameter. If the destination parameter is omitted, the file will be stored in Flash PROM with the same name as the source. Note that the ".bze" extension is required in the command. The download "method" must be "binary" (which is the default).

Example:

>download C:\load\pmp03_12.bze

download the file pmp03_12.bze from the PC directory C:\load into the unit file flash/pmp03_12

If the download is executed from a terminal connected to the Auxiliary port, the file is in ASCII format and has the extension .dwe. The download method must be "inline". The source parameter is not needed since, after issuing the command, you must initiate the transfer of the file from the terminal.

Example:

>download destination=pmp03_12 method=inline

After issuing the command initiate the file transfer using the terminal facilities.

run-file

filename=filename

Executes the specified file. The file is first copied into RAM and then the program is executed out of RAM. If the radio is rebooted or power cycled, the radio reverts back to the program defined as the default program. If the memory location is not defined (flash or tmp), the command assumes the flash directory.

Examples:

>run pmp03_04

set-default-program

filename=filename

Sets the specified file as the default program to be loaded upon reboot or power cycle. Since the default program must reside in flash memory, the "flash/" prefix is assumed and is not required for the command.

Examples:

>sdp pmp03_04

4.8 Event Logging Commands

The *pulsAR radio* keeps track of various significant events in an "event log". This event log holds up to 500 events. The first 100 entries in the log are filled sequentially after power up and are not overwritten. The remaining 400 entries consist of the last 400 events recorded. All events are time-tagged with system time.

Events are classified in different categories from level 0 (catastrophic error) to 7 (information).

clear-log

region= all-events or ***reboot-reasons***

This command clears the contents of the system event log from the specified "region". After a code upgrade it is recommended to clear the reboot reasons since the pointer in non-volatile memory pointing to the reason message may no longer be valid.

display-log

region=end or ***tail*** or ***beginning*** or ***all-events*** or ***reboot-reasons***
length=1..500
id=0..200
min-level=0..7
max-level=0..7

This command outputs to the terminal the specified **region** of the event log. The **length** parameter specifies the number of events to output (defaults to 10). The remaining parameters provide filters to leave out specific events. If the **id** parameter is specified, only the event identified by that id will be displayed. The **min-level** and **max-level** settings allow the user to display only the events with the specified category range.

When the region is specified as **tail**, the command displays the last 10 events followed by a blank line, then waits for more events and displays then as they occur. You can press the space bar to exit this mode.

The **reboot-reasons** region of the event log consist of the last four events that that caused the gateway to reboot. These events are stored in non-volatile memory. The time tag in these events is the time the gateway was up since it was rebooted, not the time of day.

Examples:

>display-log region=all

>display-log region=all length=300 min-level=2 max-level=6

max-event

Sets the event severity level that should be saved or displayed. These two parameters are saved as part of the configuration

save=0..7

Only events of the specified level or below will be saved in the event log.

print=0..7

Events of the specified level or below will be output to the console port as they occur.

Examples:

>max-event print=6

4.9 Miscellaneous commands

date

The *pulsAR radio* will set the internal radio date and time automatically by decoding Network Time Protocol (NTP) packets in the Ethernet LAN. The “zone” parameter specified with the “date” or “time” command will then be used to display the date/time in local time. The “zone” value is saved as part of the radio configuration.

If NTP packets are not available, the user can initialize the radio date and time with either the “date” or “time” commands. The parameters for both commands are identical, but the parameter order is different. The date command can be entered as:

> **date 16-may-2000 10:32:06**

date=day-month-year

Sets the date used by the radio. The day / month / year parameter may be separated by any valid separator (‘-‘ ‘/’ etc.)

time=hh:mm:ss

Sets the radio time in hours, minutes and seconds. Use colons to separate the three fields.

zone=zone-code or ***offset***

Sets the time zone to be used by the radio to translate the NTP time to local time. It can be specified by an offset from GMT (-0800 or +0200 for example), or as a “zone-code”. The valid “zone-codes” and the respective offsets are shown below:

Zone	zone code	offset
Pacific Standard Time	PST	-0800
Pacific Daylight Time	PDT	-0700
Mountain Standard Time	MST	-0700
Mountain Daylight Time	MDT	-0600
Central Standard Time	CST	-0600
Central Daylight Time	CDT	-0500
Eastern Standard Time	EST	-0500
Eastern Daylight Time	EDT	-0400
Greenwich Mean Time	GMT	0000

help [command-name]

If no command is specified, displays the complete list of commands. If a command is specified it displays the valid parameter and corresponding values for that specific command.

Examples:

>help monitor-link

history

Displays the previous commands entered.

license

key=< ASCII string>

The “license” command is used to turn ON or OFF a set of optional features or capabilities. The key is a 35-character string combination of ASCII letters, numbers, and hyphens. The key must be input with the syntax as shown in the example below, including hyphens, for the radio to accept it. The characters can be input as upper or lower case.

After entering the key you must reboot the radio for the feature, enabled by the key, to take effect.

Each key is unique for a particular radio serial number and capability, i.e. a key generated to turn ON a capability on one serial number will not work on another radio.

Example:

>license key=02EL1-ZGZ42-G0000-00C54-81WAJ-C9BEK

logout

Closes the current command session.

reboot

Resets the radio causing the software to perform a complete start up sequence. This is equivalent to power cycling the radio off and on.

time

time=hh:mm:ss
date=day-month-year
zone=zone-code or offset

This command is identical to the “date” command explained above except for the order of the parameters. It allows the time and date to be entered as:

> time 10:32:06 16-may-2000

version

Displays the radio model and software version.

5 NETWORK MANAGEMENT

The radios operate as part of a network environment with many devices. Whether operated by an Internet Service Provider (ISP) or the Information Technology (IT) department of a business, there is often a need to supervise and manage the network from a central Network Operations Center (NOC). This chapter describes the features of the *pulsAR* radio that are useful for this purpose.

5.1 Telnet

5.1.1 General

Telnet, which stands for Telecommunications Network, is a protocol that allows an operator to connect to a remote machine giving it commands interactively. Once a telnet session is in progress, the local machine becomes transparent to the user, it simply simulates a terminal as if there was a direct connection to the remote machine. Commands typed by the user are transmitted to the remote machine and the responses from the remote machine are displayed in the telnet simulated terminal.

5.1.2 Starting a Telnet Session

In order to start a telnet session with a radio you first need to configure the radio with a unique valid IP address. This is done with the ***ip-configuration*** command described in section 4. This initial configuration must be done using either the RS-232 console port or the Econsole program.

Once the radio has an IP address, you must start the telnet application at the local machine and establish a connection with the IP address of the radio. If the local machine is a PC running Windows, you can start Telnet through Hyperterminal as follows:

1. Start the Hyperterminal application (in a typical Windows installation Hyperterminal can be found from the **Start** button under Programs/Accessories/Communications…)
2. From the **File** menu choose **New Connection**.
3. In the **Name** field enter any name you wish and press the OK button. This will open the "Connect To" window.
4. In the last field, titled "**Connect using**:", select **TCP/IP (Winsock)**. The fields above will change to **Host Address:** and **Port Number:**.
5. In the **Host Address** field, type the IP address of the radio, then press the OK button.
6. TCP will now attempt to connect to the specified device. If successful the radio will request a login name with the prompt **login:**
7. Type ***public*** followed by the Enter key

The radio will now display its prompt command and you may type any commands as described in section 4.

If after entering the ***public*** login name, the terminal displays the message "Login Failed", this may be due to the radio being configured to be managed from only some specific IP addresses. This is explained in the following section.

5.1.3 Telnet Security

The remote management capability through Telnet opens the possibility for an unauthorized user to login to any radio accessible through the Internet. The radio configuration can be password protected with the use of the **lock** and **unlock** commands. If further security is desired you can specify up to four source IP addresses that are authorized to initiate Telnet sessions with the radio. When configured in this way, the radio will reject Telnet requests from all IP addresses that are not in the authorized list.

The authorized source IP addresses for Telnet are the same addresses that are authorized to perform SNMP management. They are entered using the ***snmp*** command described in section 4 and can be viewed with the ***display-configuration*** command. When this list is empty, you can initiate a Telnet session from any IP address with the login name ***public.*** When this list is not empty, Telnet sessions can only be initiated from the listed hosts. Additionally, for each host, the login name must match the string listed for the ***community*** field.

If you wish to use this security feature you need to know the IP address of the local machine. On a PC running Windows, one way to find its IP address is to open a DOS window and issue the command:

```
>ipconfig
```

5.2 SNMP

5.2.1 Command Line Interface Versus SNMP

Configuration settings on the *pulsAR* radio are displayed and modified using a command line interface, which can be accessed using either the RS-232 console port, the Econsole program, or via a Telnet session.

In a NOC environment, there is a need for an automated monitoring system to collect on an ongoing basis information from devices in the network for three purposes:

1) to build an inventory of all the devices of the network

2) to keep track of all devices on the network and raise alarms when any device becomes unreachable (device failed, link down, etc)

3) to maintain statistics on traffic levels in order to implement usage-based charging, or to determine where congestion exists in the network, so that the network can be expanded to accommodate growth

Command line interfaces are not very suitable for these purposes, and the *pulsAR* radio supports the Simple Network Management Protocol (SNMP) to assist in these tasks. SNMP is a simple, transaction-based (command/response) protocol, which allows a variety of third-party software products to query network devices and collect data for these purposes.

For a generic introduction to the SNMP protocol, we recommend the book "The Simple Book - An Introduction to Internet Management" by Marshall T Rose (P T R Prentice-Hall, 1994).

5.2.2 What is SNMP?

The SNMP protocol is described in the following documents:

- RFC1157 - Simple Network Management Protocol (SNMP) - ftp://ftp.isi.edu/in-notes/rfc1157.txt
- RFC1155 - Structure and identification of management information for TCP/IP-based internets - ftp://ftp.isi.edu/in-notes/rfc1155.txt
- RFC1213 - Management Information Base for Network Management of TCP/IP-based internets: MIB-II - ftp://ftp.isi.edu/in-notes/rfc1213.txt

SNMP is a specification for the interaction (***protocol***) between the ***SNMP agent*** embedded in a network device, and the ***SNMP manager*** software running on another machine in the network.

The data provided by the SNMP agent in a network device is described by a document called the MIB (Management Information Base). **MIB-II** describes the basic information provided by all devices, and additional documents describe optional extensions for components that may not exist in most devices.

Devices may also provide non-standard MIB groups. In order for a network management system to make use of these extended features, the MIB description must be obtained from the device manufacturer and loaded into the management station.

SNMP data travels in IP packets, using the UDP port 161 for the agent, so in order to use SNMP, the device must have an IP address.

5.2.3 Security Considerations in SNMP

SNMP was designed before the Internet grew commercial, and the original design was not secure. Later versions intended to provide security, but grew cumbersome and complex. As a result, most devices provide secure operation in a non-standard way.

The original SNMP design as embedded in the protocol, assigns network devices to named communities. Any transactions exchanged between the agent and the manager include the name of the community to which they both belong. The agent has a list of which access rights (set, get, trap) it will grant for each community of which it is a member.

In the *pulsAR radio*, this has been re-interpreted: The radio has a list of up to 4 management stations from which it will accept requests, and for each one - identified by its IP address - it is indicated what access rights it is granted, and which community string it must use. Requests from all other sources are ignored. Refer to the ***snmp*** command in section 4 for details on how to configure the radio for management using SNMP..

If no management stations are listed, ***get***-requests with the community ***public*** will be accepted and responded to from any IP address.

5.2.4 Examples of Network Management Systems

Some of the most common network management systems are listed below. All of them provide many similar features, including network status displays showing key devices on a map, where the devices change color if they have alarms, and with provisions for activating a remote paging device if there is a problem.

WhatsUp Gold (Ipswitch Inc)
http://www.ipswitch.com/
USD 800 (approx)

SNMPc (Castle Rock Computing, Inc)
http://www.castlerock.com/
USD 900 to USD 2700 (approx, depending on options)

OpenView (Hewlett-Packard)
http://www.openview.hp.com/
USD 3,000 to USD 10,000
The OpenView product line has been revamped; HP is now positioning it not as a turnkey software product, but as a custom adapted application to be bought through a value-added implementation partner.

Multi-Router Traffic Graphing
http://www.mrtg.org/
This is a free, open-source software, capacity planning tool.

5.2.5 *pulsAR* radio Management Information Base (MIB)

The *pulsAR radio* implements only the core MIB-II. A management station will see three interfaces in the ***interfaces group***:

1 - Bridge

2 - Ethernet

3 - Radio

The first of these represents the attachment of the SNMP agent to the bridged network. Only IP traffic seen by the embedded host is counted.

The ethernet device (***ifIndex=2***) represents the traffic passing through the radio's ethernet port. This is what should be tracked by MRTG.

The third device represents the wireless transceiver. If will appear as ***down*** if the radio does not have a working link to its peer. This is useful for confirming the loss of a link. The traffic counts show all packets to and from the radio, including handshaking between the two radios radios.

5.3 UDP Command and Data Interface

5.3.1 Purpose

The *pulsAR radio* firmware includes an optional command/data interface based on the UDP/IP protocol. This interface can be used for two purposes:

1. As a command interface allowing radio text commands and replies to be encapsulated in UDP/IP packets. This is useful when you want to configure the radio from a program running on an external computer
2. To send and receive **vital packets** which the radio classifies as the highest priority.

With the UDP Command Interface a host computer can issue all the same text commands available through the other interfaces and described in the radio Operator's Manual. The command text, in ASCII, must be encapsulated in an UDP/IP packet addressed to the radio. The radio replies to every command with text also encapsulated in an UDP/IP packet. This reply packet can be addressed to a pre-configured IP address or to the device that generated the command. See the **udp-configuration** command in section 4 for the options to configure this udp interface.

5.3.2 UDP Command Packet formats

Table 5.1 below shows the structure of the UDP command and reply packets. The host computer always initiates the command, and the radios reply to every command. The command sequence number field, in the reply, "echoes" the contents of the sequence number field in the command.

If the socket-mode is set to 2, the radio issues an "unsolicited reply" message on power up to the configured peer-address. This can be used to alert a host that the radio just rebooted. The command sequence number in this power up unsolicited reply is always zero.

The command and reply text is in ASCII. Refer to section 4 for a complete list of all valid commands. Prior to using the UDP interface you must initialize the radio IP and the UDP configuration (using commands **ip-configuration** and **udp-configuration**) through either the RS-232 console or the Ethernet port using the Econsole utility.

Table 5.1. UDP Command / Reply Packet Format

Bytes	**Host to Radio (Command)**	**Radio to Host (reply)**	
0-5	Dest MAC address	Dest MAC address	Ethernet Encapsulation
6-11	Src MAC address	Src MAC address	
12-13	0x0800	0x0800	
14-33	IP header	IP header	UDP/IP encapsulation RFC-768 (UDP) RFC-760 (IP).
34-35	Src port (any)	Src port: radio UDP cmd port	
36-37	Dest port: radio UDP cmd port	Dest port: UDP peer cmd port	
38-39	Length of UDP payload (6-500)	Length of UDP payload (6-500)	
40-41	Checksum	Checksum	
42-45	Command Sequence number	Command Sequence number	Payload
46-47	Pad (all zeroes)	Reply code	
48-	Command text	Reply text	

The values of the "reply code" field are shown in the following table.

Table 5.2. Reply Code Field

Code	Mnemonic	Description
0	CMD_SUCCESS	Command executed successfully
1	CMD_RESTART	Unsolicited reply at startup. A **start** command must be given.
2	CMD_TRUNCATED	Response text overflow (truncated if over the value specified by max-response-bytes)
3	CMD_NOT_FOUND	Unknown Command
4	CMD_AMBIGUOUS	Ambiguous abbreviation
5	CMD_BAD_ARG_NAME	Illegal or ambiguous argument name
6	CMD_BAD_ARG_VALUE	Argument value out of range
7	CMD_ARG_MISSING	Required argument missing
8	CMD_FAILED	Command failed
9	CMD_DISABLED	A **start** command must be given

.

6 RF LINK DESIGN

6.1 Antenna Selection

The *pulsAR* radio comes equipped with two antenna ports to connect to external antennas. The two ports are typically used with the Mesh/Tree network topology described in section 2. Afar carries the following antennas which cover the needs of most typical applications.

Band	**Antenna Type**	**Gain**	**AFAR Model Number**
900 MHz	Omni-directional	5 dBi	ATO-0905
	Yagi	9 dBi	ATD-0909
	Dish Reflector	15 dBi	ATD-0915
2.4 GHz	Omni-directional	9 dBi	ATO-2409
	Panel	16 dBi	ATD-2416
	Panel	19 dBi	ATD-2419
	Dish Reflector	24 dBi	ATD-2424

The “gain” of the antenna is a measurement of how much it focuses its radiated energy in a specific direction or plane. An “omni-directional” antenna for example radiates its energy over 360 degrees in the horizontal plane but has a much poorer radiation in the vertical plane. In most applications you don’t need to radiate vertically (into the sky or into the ground) so by focusing the energy in the horizontal plane you achieve a reasonable gain.

Omni-directional antennas are a good choice for a hub radio in a point-to-multipoint application when the remote radios are all around. If the remote radios happen to be all located in one particular “sector” when viewed from the hub location then you can use a “sectorial” antenna that focuses the energy in that general direction. There are antennas that cover sectors with different angles, for example, 30, 60, 90 and 120 degrees. The narrower the angle the higher the gain of the sectorial antenna.

At fixed remote radios, or in a point-to-point link, you should select high gain directional antennas that focus all the radiated energy in one specific direction. These antennas not only provide a much higher gain and therefore increased radio ranges and link margins, but also protect your link from unwanted interference coming from other directions.

In mobile applications you typically need omni-directional antennas on the moving vehicle so that the vehicle can change its orientation and stay connected to say, a fixed hub.

Antenna Polarization

The electro-magnetic waves radiated from an antenna are typically "polarized" meaning that the waves are constrained to oscillate in one specific direction. The most common polarizations are vertical (the waves oscillate up and down) or horizontal (right and left).

Note that this polarization is independent of the direction of wave propagation. For example the omni-directional antennas described above radiate the energy along the horizontal plane (waves propagate preferentially in that plane) but the oscillation of the electro-magnetic field can still be either vertical or horizontal (polarization).

In the case of directional antennas (yagis, panels, or parabolic reflectors), you can mount the antenna with either vertical or horizontal polarization by simply rotating the complete antenna assembly by 90 degrees. Most omni-directional antennas on the other hand consist of a vertical radiating element that can only be mounted for vertical polarization (although, as mentioned above, you can get omni-directional antennas with horizontal polarization).

It is essential that the two antennas at both ends of one RF link have the same polarization. Differences in polarization among antennas – called "cross-polarization" – will reduce the signal strength considerably.

The choice of polarization – horizontal vs. vertical – is in many cases arbitrary. However, interfering signals from such devices as cellular phones and pagers are generally polarized vertically, and an excellent means of reducing their effect is to mount your system antennas for horizontal polarization.

6.2 RF Path Analysis

6.2.1 Line-of-Sight Requirements

At UHF and microwave frequencies, when you deploy an RF link between two distant sites you need to make sure you have "line of sight" between the two antennas. But at these frequencies "line of sight" does not simply mean that from one site you can "see" the other.

For short ranges, a degree of obstruction may be acceptable. The radio has some ability to "penetrate" trees and other foliage, specially the 900 MHz models. On the other hand, geographical features (hills) and large buildings are likely to interfere with communications, and antennas should be elevated to see each other above such objects.

For links covering very long distances (exceeding 5 miles or 8 km) you also need to take into account the following factors:

- The curvature of the earth.
- Fresnel Zone clearance.
- Atmospheric refraction.

Figure 6.1 illustrates these concepts with an exaggerated representation of a long link. The following sections describe these effects. You can use our free "Fresnel Zone Calculator", shown in figure 6.2, to make all the computations for the RF path analysis and determine if you have adequate antenna height for your links. The calculator is available on our website at *http://www.afar.net/fresnel-zone-calculator/*

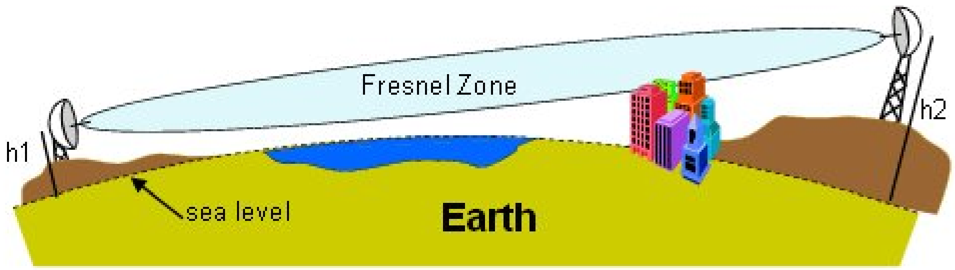


Figure .6.1 – Earth curvature, Fresnel Zone and antenna heights

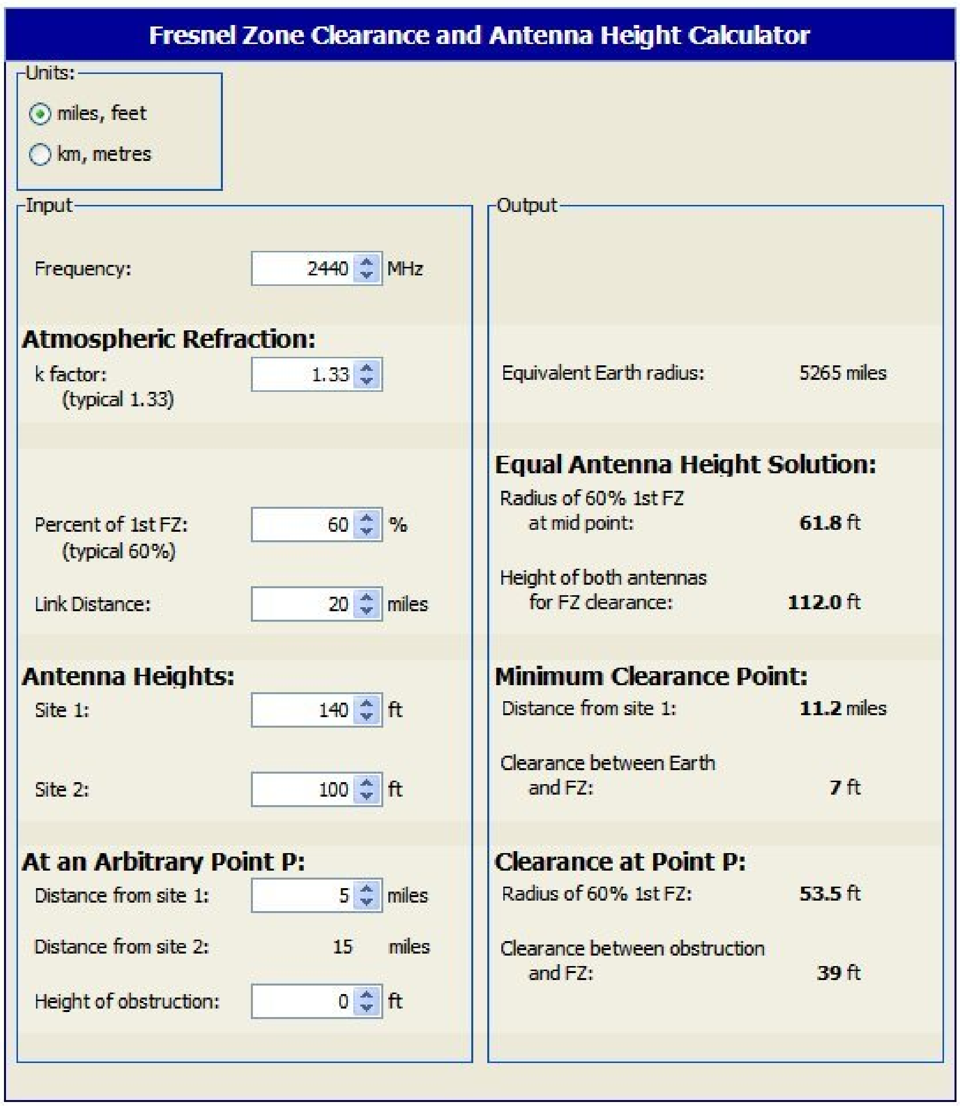


Figure 6.2– Fresnel Zone Calculator

6.2.2 Earth curvature

With long links the earth curvature can prevent the two antennas from seeing each other. This is illustrated in tables 6.2 and 6.3, which show the minimum antenna heights required, at both ends of the link, to simply clear the earth surface at various distances. As the distance grows the effect worsens requiring you to have access to high elevation points to deploy such links. The values in the table used a typical atmospheric refraction factor of 4/3 (see below).

6.2.3 Fresnel Zone

The Fresnel zone is a long ellipsoid that stretches between the two antennas. The **first** Fresnel zone is such that the difference between the direct path (AB) and an indirect path that touches a single point on the border of the Fresnel zone (ACB) is half the wavelength (see figure 6.3).

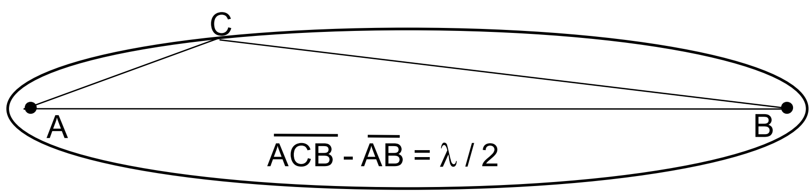


Figure 6.3– Fresnel Zone Definition

If a significant portion of the Fresnel Zone is obstructed the receive-signal-strength at the receiving antenna can be significantly attenuated. A rule of thumb is that you need at least 60% of the first Fresnel Zone clear of any obstructions in order for the radio wave propagation to behave as if it is in "free space".

Even though at 2.4 GHz half of the wavelength is only 2.4 inches (6.2 cm), at long distances the radius of this ellipsoid can be quite large. This is illustrated in tables 6.2 and 6.3, which show the radius of this (60%) ellipsoid at the mid-point for various distances.

Table 6.2 – Antenna heights (meters) to clear the earth and 60% of the Fresnel Zone (2.4 GHz)

Distance (km):	5	10	20	30	40	50	60	70
Antenna height to clear earth (meters):	0.4	1.5	6	13	24	37	53	72
60% Fresnel Zone radius at mid-point (meters):	7.5	10	15	18	21	23	26	28
Total antenna height required (meters):	7.9	12	21	31	45	60	79	100

Table 6.3 – Antenna heights (feet) to clear the earth and 60% of the Fresnel Zone (2.4 GHz)

Distance (miles)	5	10	20	30	40	50
Antenna height to clear earth (ft)	3	12	50	113	200	313
60% Fresnel Zone radius at mid-point (ft)	31	44	62	76	87	98
Total antenna height required (ft)	34	56	112	189	287	412

6.2.4 Atmospheric Refraction

Under normal atmospheric conditions radio waves do not propagate in a straight line, they actually bend slightly downward. This is due to "refraction" in the atmosphere that affects radio waves propagating horizontally. To take this downward bending into account, we perform all the RF path calculations using a larger value for the earth radius, such that we can then consider the radio waves as propagating in a straight line.

In the Fresnel Zone calculator you can change the earth radius multiplying factor (the "k factor") to take into account different atmospheric conditions. Under normal conditions the "k factor" is 4/3. However unusual weather conditions can cause significant changes to the refraction profile. For a high reliability link you may want to use a lower value for the k factor.

6.2.5 Clearing Obstructions

The calculator allows you to quickly determine whether you have enough clearance above a particular obstruction in the RF path, or alternatively, how high you need to elevate your antennas to clear the obstruction.

For each potential obstruction in the path you need to know its distance from one of your end points and the height of the obstruction. Drawing the path in “Google Earth” is a quick way of identifying buildings or structures that lay in the direct path and finding their distance from the end points. You may need to use a topographic map, draw the line between the end points, and create an accurate terrain profile. If there are buildings or trees in the path you need to determine or estimate their height and add it to the terrain elevation at those points.

For each of these potential obstruction points, enter its distance from site 1 and the height of the obstruction above sea level in the bottom left input “spinners” of the calculator. On the right hand side the calculator displays the vertical separation between the top of the obstruction and the bottom of the Fresnel Zone. If this value is negative you can use the antenna height spinners to increase the height of one or both antennas until that clearance becomes greater than zero.

6.3 RF Link Budget Calculations

If you have radio-line-of-sight for your link (as explained in the previous section), then it is easy to compute the receive-signal-strength at the receiving radio and from there determine if you have an adequate "fade margin".

You can use our free "RF Link Budget Calculator", shown in figure 6.4, to make all the required computations and evaluate the trade-off between antenna gains, cable losses etc. The calculator is available on our website at *http://www.afar.net/rf-link-budget-calculator/*

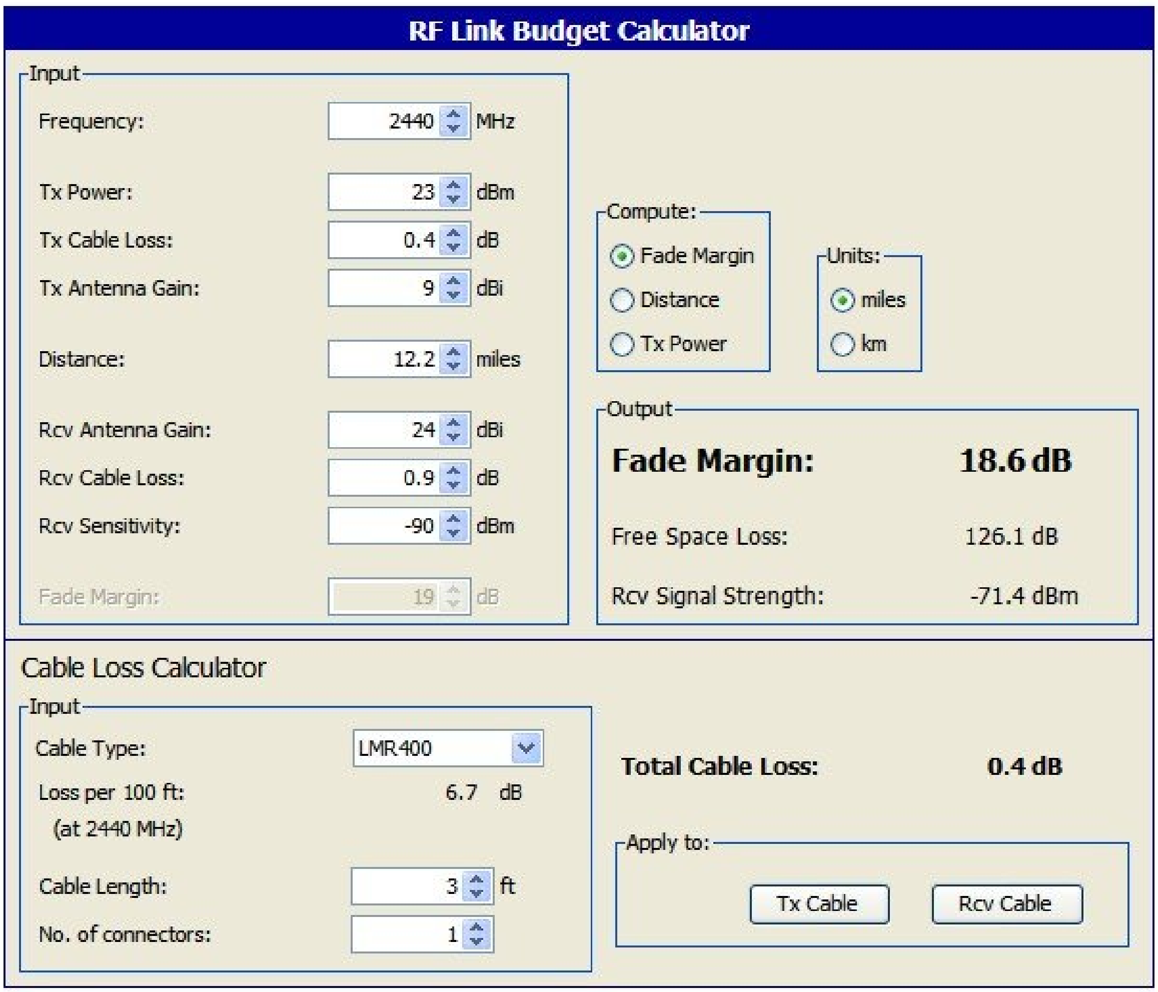


Figure 6.4: RF Link Budget Calculator

Even though your link is bi-directional, in the calculator Site 1 is viewed as the transmitter and Site 2 as the receiver. If you configure both radios with the same transmit power the results for both directions are identical. If you configure the transmit power of the two radios to different values you should compute the link budget in each direction separately.

The RF link budget calculations are made a lot easier by using "deciBel" units (dB). The deciBel is a logarithmic scale that compares a parameter value against a specific reference. The advantage of working in dB is that you can simply add all the parameters that boost your signal and subtract the ones that attenuate it.

The following paragraphs follow an RF signal from the transmit radio to the receive radio, explaining the various parameters and how they apply to the *pulsAR* radio

Transmit Power

The RF signal starts at the output of the radio at Site 1 with a specific transmit power. In the *pulsAR* radio you can configure that power from 0 to 23 dBm (the "m" in the dBm unit indicates that this power is measured relative to 1 milliwatt).

Cable Losses

The radio is connected to the antenna through an RF coaxial cable. As the signal propagates through this cable it is attenuated. The total attenuation (loss) depends on the frequency, cable type, cable length and number of connectors. You can use the "Cable Loss Calculator" (at the bottom of the RF Link Budget calculator), which includes the characteristics for several RF cable types. If your cable is not listed you can also enter its "loss per 100 ft" (or loss per meter) at 2.4 GHz and the calculator computes the total loss. Note that each connector along the way introduces additional attenuation, typically around 0.2 dB per connection.

The p*ulsAR* radio is housed in a watertight enclosure so that you can mount it in very close proximity to the antenna. That way you can keep the RF coaxial cable very short and therefore reduce these losses.

Antenna Gain

The transmit signal is radiated through the antenna at Site 1. The antenna focuses the radiated energy in a specific direction or plane, boosting your signal strength in that specific direction. That boost is measured by the "antenna gain" in dBi (the "i" in the dBi unit indicates that the antenna gain is measured in relation to an **i**sotropic radiating element).

Distance and Free Space Loss

Once the signal is in the air it propagates towards the receiver but suffers attenuation as it radiates away from the transmitter. If there are no obstructions the total attenuation is called the Free-Space-Loss (FSL). This loss is a function of the frequency, f, and the distance, d. It can be computed, in dB, from the following expressions:

$$FSL = 32.4 + 20 \log \mathbf{f} + 20 \log \mathbf{d} \quad \text{(with } \mathbf{f} \text{ in MHz and } \mathbf{d} \text{ in km)}$$

or

$$FSL = 36.6 + 20 \log \mathbf{f} + 20 \log \mathbf{d} \quad \text{(with } \mathbf{f} \text{ in MHz and } \mathbf{d} \text{ in miles)}$$

The calculator computes this loss for you and displays it in the output panel. An easy rule to remember is that the free space loss increases by 6 dB every time you double the distance.

Receive Signal Strength

The signal is much weakened when it reaches the receiving antenna. That antenna will give it a boost, measured by the antenna gain in dBi. The signal is then attenuated as it propagates down the RF coaxial cable that connects that antenna to the radio. The Receive Signal Strength (RSS) parameter refers to the strength of the signal that finally arrives at the RF connector of the receiving radio at site 2. With all the gains and losses measured in dB, this receive signal strength is computed with the following expression:

RSS = TxPower – CableLoss1 + AntGain1 – FSL + AntGain2 – CableLoss2

The RF Link Budget calculator always computes and displays this value in the output panel.

Receive Sensitivity

The radio Receiver Sensitivity is the receive-signal-strength at the input of the radio at which point its "Bit Error Rate (BER)" is at a specified value. Most manufacturers, including Afar, use a BER of $1x10^{-6}$ (1 bit error in one million bits) to specify the radio receiver sensitivity. However make sure you check the specifications when comparing the sensitivity in radios from different manufacturers.

You can configure the *pulsAR* radio to operate at four different RF speeds. Lower speeds give you a better receiver sensitivity. Appendix B lists the sensitivity for the various models and at the different RF speeds. Use the correct sensitivity value from the radio specification

Fade Margin

The Fade Margin is the difference between the Received Signal Strength and the radio Receiver Sensitivity. When you deploy a link you want to have a Receive Signal Strength that is sufficiently above the radio Receiver Sensitivity in order to survive signal fading due to a variety of factors. These factors might include slight misalignment of the antennas, losses due to fog and rain, etc. As a rule of thumb you should try to get at least 15 dB of fade margin in your links.

With the calculator you can select whether to compute the Distance, the Fade Margin or the Transmit Power. All these parameters are inter-related as described above. When you select one parameter to compute, its value in the input panel is disabled.

All the input values are controlled with “spinners”. As you change any input the calculator instantly updates the output values. By seeing the results immediately you can quickly evaluate trade-offs between different parameters.

APPENDIX A – Command Summary

This appendix lists all commands organized in the respective functional groups. Parameters that are part of the radio configuration are identified by having an entry under the "Factory Configuration" heading. When entering a command, if a parameter that is part of the radio configuration is omitted, the value for that parameter is not modified.

For commands that are not part of the radio configuration, if a parameter is omitted, the value for that parameter defaults to the value indicated in bold.

Configuration Management Commands

Command	Parameters	Values
change-password	enable-configuration	<string>
display-configuration	source	**current** main alternate basic factory
load-configuration	source	**main** alternate basic factory
lock		
save-configuration	destination	**main** alternate
unlock	enable-configuration	<string>

Major Configuration Parameters

Command	Parameters	Values	Factory Configuration
distance-max	maximum	10/01/00	80
	units	km or miles	km
encryption	mode	off, des-56, 3-des-112, aes-128, aes-256	off
	key	(hexadecimal)	
	key-phrase	<string>	
ethernet	speed	auto-10, 10hdx, 10fdx 100hdx, 100fdx, auto, off	auto
	timeout-sec	5..10000	30
	multi-cast-timeout-sec	5..10000	30
node	type	hub, remote, root-1, root-2, branch, leaf	remote
	max-remotes	1..32	32
	name	(23 character string)	rmt-nnnnn
	network-id	0..65535	0
	location	(25 character string)	
	contact	(25 character string)	
rf-1-setup	antenna	a, b	rf-1: a, rf-2: b
rf-2-setup	receive-channel	min..max (appx C)	rf-1: 12 rf-2: 25
	transmit-channel	min..max (appx C)	rf-1: 12 rf-2: 25
	speed-mbps	[speeds] (appx B)	max
	power-dbm	0..26 (900 MHz models) 0..27 (2.4 GHz models)	18
single-node-reboot	timeout-sec	0,15..60000	900
time-division-duplex	sync-mode	off, auto	auto
	cycle-period-ms	20, 40	20
	split-outbound-percent	auto, 10, 20, 30, 40, 50, 60, 70, 80, 90	auto

Internet Protocol (IP) Management Commands

Command	Parameters	Values	Factory Configuration
ip-configuration	address	ip address	
	netmask	ip address	
	gateway	ip address	
	dhcp-client	on, off	off
ping	destination	ip address	
	count	0..500 (def **4**)	
	size-bytes	32..1400	
snmp	manager	ip address	
	community	ASCII string (9 max)	
	access	g, gs, gt, gst	
	authentication-traps	0, 1	
	delete	1..4	
udp-configuration	console	on, off	off
	vital-port-1	1..0xFFFF	0
	vital-port-2	1..0xFFFF	0
	command-port	1..0xFFFF	422
	max-response-bytes	400..65521	512
	socket-mode	1, 2	1
	peer-address	ip address	
	peer-command-port	1..0xFFFF	0

Installation and Link Monitoring Commands

Command	**Parameters**	**Values**	**Factory Configuration**
antenna-alignment-aid	mode	off, a-antenna, b-antenna	off
monitor-flow			
monitor-link	node	**0,**1,4-N	
	clear	**0**, 1	
monitor-roaming			
show-tables	table	**status,** links, tree, radios, ethernet, ip-stack, econsole, properties	
	format	**count** times	
spectrum-analysis	antenna	**a**, b	
	display	**graph** table	
	dwell-time-ms	1…1000 (def: **100**)	
time-analysis	channel	0..50	
	antenna	**a,** b	
	display	**graph** table	
	dwell-time-ms	1, 2, 5, 10, **20**, 50, 100, 200, 500	

File Utilities

Command	Parameters	Values
console-speed-bps	baud-rate-bps	9600, 19200, 38400 57600, 115200
copy-file	source	filename
	destination	filename
delete-file	filename	filename
directory	format	**short** full
download-file	source	path/filename
	destination	path/filename
	method	binary inline
run-file	filename	filename
set-default-program	filename	filename

Event Logging Commands

Command	Parameters	Values	Factory Configuration
clear-log	region	**all-events** reboot-reasons	
display-log	region	**end** tail beginning all-events reboot-reasons	
	length	1..500 (def **10**)	
	id	0…200	
	min-level	0…7 (def: **0**)	
	max-level	0…7 (def: **7**)	
max-event	save	0..7	5
	print	0..7	3

Miscellaneous Commands

Command	Parameters	Values	Factory Configuration
date	date	dd-mmm-yyyy	
	time	hh:mm:ss	
	zone	offset or code	GMT
help	command		
history			
license	key	<35 character string>	
logout			
reboot			
time	time	hh:mm:ss	
	date	dd-mmm-yyyy	
	zone	offset or code	GMT
version			

APPENDIX B – Specifications

RF Specifications	AR-9010E	AR-9027E	AR-24010E	AR-24027E	AR-24110E
RF Frequency Band (MHz)	902 to 928	902 to 928	2400 to 2483	2400 to 2483	2400 to 2483
Signal Bandwidth (-20 dBc)	1.6 MHz	4.6 MHz	1.6 MHz	4.6 MHz	17 MHz
RF Channels (non-overlap):	13	4	35	11	3
Transmitter Output Power:	0 to 26 dBm	0 to 26 dBm	0 to 27 dBm	0 to 27 dBm	0 to 27 dBm
Receiver Sensitivity (10^{-6} BER) and Data Rates	(dBm) (kbps) -103 @ 100 -100 @ 200 -98 @ 550 -95 @ 1100	(dBm) (kbps) -100 @ 250 -97 @ 500 -95 @ 1375 -92 @ 2750	(dBm) (kbps) -100 @ 100 -97 @ 200 -95 @ 550 -92 @ 1100	(dBm) (kbps) -98 @ 250 -95 @ 500 -93 @ 1375 -90 @ 2750	(dBm) (kbps) -94 @ 1000 -91 @ 2000 -89 @ 5500 -86 @ 11000
Maximum Receive Signal	-30 dBm (to stay in receiver linear region) +20 dBm (to avoid damage)				
Modulation Type	direct sequence spread spectrum				
Ethernet Port					
Speed	10/100 BaseT, full/half duplex, auto-negotiate				
Connector	8 pin circular (Lumberg 0321-08) - RJ45 at the power inserter				
Networked Operation					
Network topologies	Point-to-point, point-to-multipoint, Mesh/Tree, Linear Network, Loop, Roaming				
Management	Telnet, SNMP (MIB2), or Econsole reach any node over wireless				
Security	DES, Triple-DES, AES-128, AES-256 encryption, 32 bit network ID / password.				
Console / Diagnostic Port					
Interface	RS-232/V.24, asynchronous 9600 to 115 kbaud				
Connector	3 pin circular (Lumberg 0321-03) - cable adapter to DB9 available				
Power					
Input Voltage	DC: Power over Ethernet (IEEE 802.3af) or +10 to +58 VDC AC: 110 to 220 VAC (with external power inserter)				
Power Consumption	Idle (link up with little or no data): 1.5 W Rx: 2.8 W Tx (900 MHz models): < 3.9 W Tx (2.4 GHz models): < 6.8 W				
Transient Max. Peak Power	1500W (with 10/1000 us waveform)				
Transient Max. Peak Current	35 A (with 10/1000 us waveform as defined by R.E.A.)				
Environmental					
Temperature	-40 to +70 deg C (-40 to +158 deg F)				
Humidity	Up to 95% non-condensing				
Water and dust protection	IP66 (Ingress Protection rating per IEC 60529)				
Mechanical					
Dimensions	4.72" wide x 8.66" high x 2.20" deep (120mm W x 220 H x 56 D)				
Weight	3.4 lbs. (1.5 kg).				

APPENDIX C – Channel Frequencies

900 MHz Models:

The center frequency of each channel can be determined by the following expression:

Freq(MHz) = 900 + Channel_number:

The following tables show all the channel frequencies, channel ranges for each model, and suggested assignments to get wide separation between channels.

Chan	Freq (MHz)	Chan	Freq (MHz)	Chan	Freq (MHz)
1		11	911	21	921
2		12	912	22	922
3	903	13	913	23	923
4	904	14	914	24	924
5	905	15	915	25	925
6	906	16	916	26	926
7	907	17	917	27	927
8	908	18	918	28	
9	909	19	919	29	
10	910	20	920	30	

	AR-9010E	AR-9027E
Channel ranges	3..27	5..25

Model	Number of Non-Overlapping Channels	Suggested Channel Allocation	Frequency Separation (MHz)
AR9010E	13	3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25,27	2.0
	9	3, 6, 9, 12, 15, 18, 21, 24, 27	3.0
	7	3, 7, 11, 15, 19, 23, 27	4.0
	5	5, 10, 15, 20, 25	5.0
AR9027E	4	6, 12, 18, 24	6.0

2.4 GHz Models:

The center frequency of each channel can be determined by the following expression:

Freq(MHz) = 2400 + 2 x Channel_number:

The following tables show all the channel frequencies, channel ranges for each model, and suggested assignments to get wide separation between channels.:

Chan	Freq (GHz)	Chan	Freq (GHz)	Chan	Freq (GHz)	Chan	Freq (GHz)
1	2.402	11	2.422	21	2.442	31	2.462
2	2.404	12	2.424	22	2.444	32	2.464
3	2.406	13	2.426	23	2.446	33	2.466
4	2.408	14	2.428	24	2.448	34	2.468
5	2.410	15	2.430	25	2.450	35	2.470
6	2.412	16	2.432	26	2.452	36	2.472
7	2.414	17	2.434	27	2.454	37	2.474
8	2.416	18	2.436	28	2.456	38	2.476
9	2.418	19	2.438	29	2.458	39	2.478
10	2.420	20	2.440	30	2.460	40	2.480

	AR-24010E	AR-24027E	AR-24110E
Channel ranges	1..40	2..39	5..35

Model	Number of Non-Overlapping Channels	Suggested Channel Allocation	Frequency Separation (MHz)
AR24010E or AR24027E	13	3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39	6.0
	10	2, 6, 10, 14, 18, 22, 26, 30, 34, 38	8.0
	8	3, 8, 13, 18, 23, 28, 33, 38	10.0
AR24110E	4	5, 15, 25, 35	20
	3	5, 20, 35	30

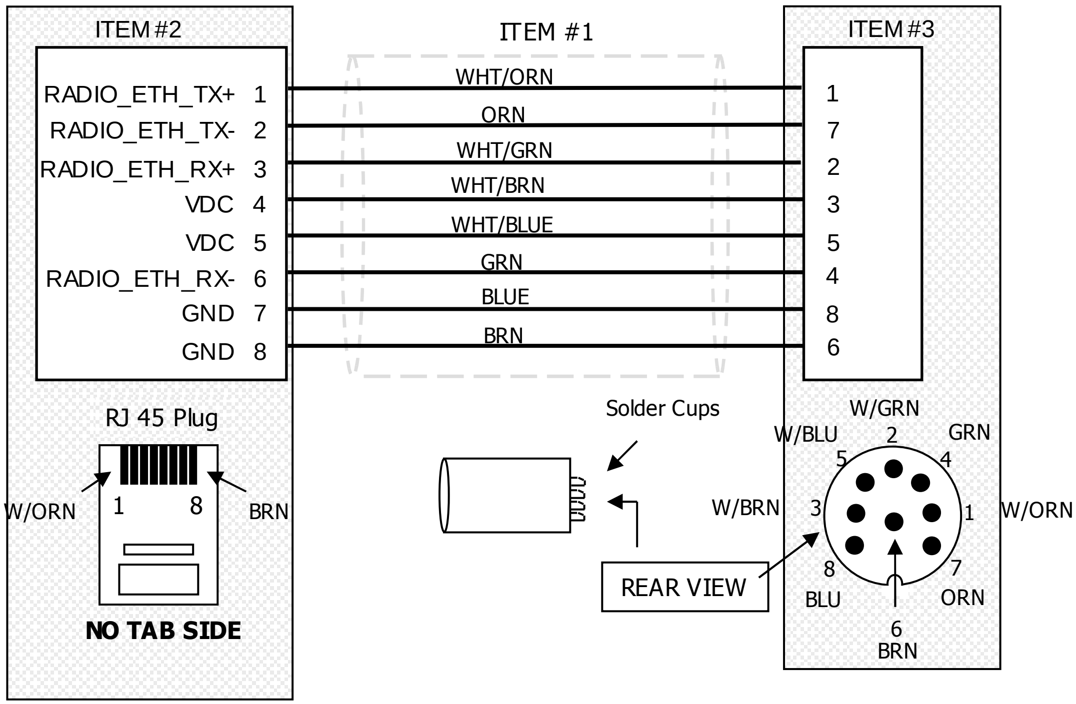
APPENDIX D – Cable Diagrams

The next two pages show the assembly drawings for the cables used to connect the Radio to a Power Inserter Unit (CAT5), and a Console cable for connection to a standard computer terminal used for Radio configuration and monitoring.

NOTES:

1. Use proper crimp tool for Item #2 connection
2. Remove cable filler gel from conductors before inserting into Item #2.
3. Insure that all eight conductors reach to end of interior channel before crimping Item #2.
4. Add label near item #2 "Afar Communications / CBL-0503-XXX" where XXX is cable length in feet. For cables shorter than 3 ft, the length is shown as AXX where XX is in inches.

APPLICATION		REVISION			
NEXT ASSY	USED ON	REV	DESCRIPTION	DATE	APPROVAL
		A	Initial Release	09/15/03	J.B
		B	Added short lengths	05/10/05	N. B



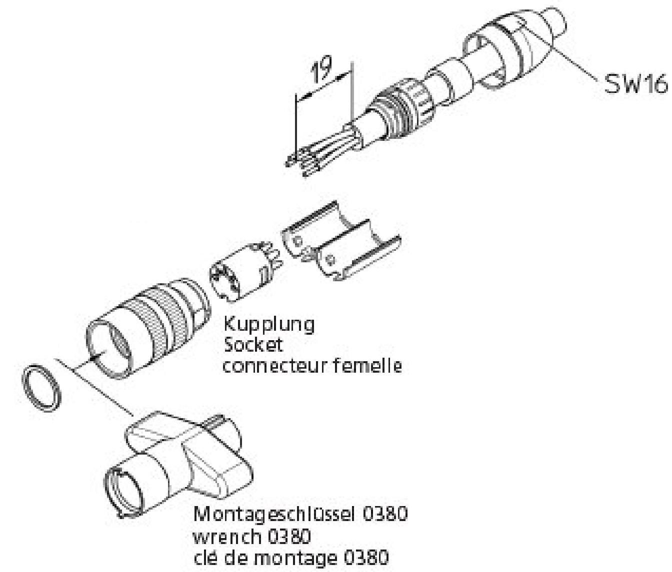


Fig. A Five pin connector is shown. Use same process for 8 pin.

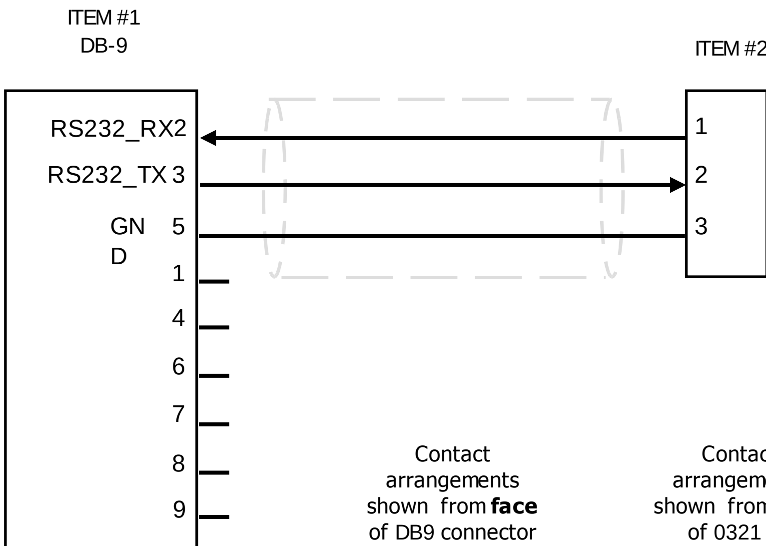
Cable Length (in feet or inches) specified in part number
CBL-0503-050 for a 50 feet cable
CBL-0503-A20 for a 20 inch cable (use for cables shorter than 3 ft)

MATERIAL

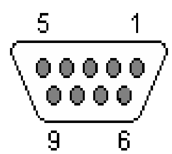
ITEM	PART NO.	MANUFACTURER	DESCRIPTION
1	5EXH04P24-BK-R-CMS-PV	CommScope	Cable, CAT5, Outdoor, Solid Cond.
2	AT8X8SC-2224	Allen Tel	Plug Connector, 8 Cond., RJ45-type
3	0321 08 or 0322 08 (fig. A)	Lumberg USA	8 Pin Field Connector, Female

DRAWN BY J. Becker	DATE 9/15/03	**AFAR Communications, Inc.**	
CHECKED BY	DATE	TITLE CAT5 ETHERNET & POWER CABLE	
APPROVED	DATE	DRAWING NO. CBL-0503-XXX	REV B
APPROVED	DATE	SCALE NONE	SHEET 1 OF 1

APPLICATION		REVISION			
NEXT ASSY	USED ON	REV	DESCRIPTION	DATE	APPROVAL
		A	Initial Release	09/16/03	J.B

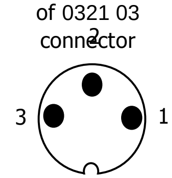


Contact arrangements shown from **face** of DB9 connector



ITEM #1
DB-9

Contact arrangements shown from **rear** of 0321 03 connector



ITEM #2

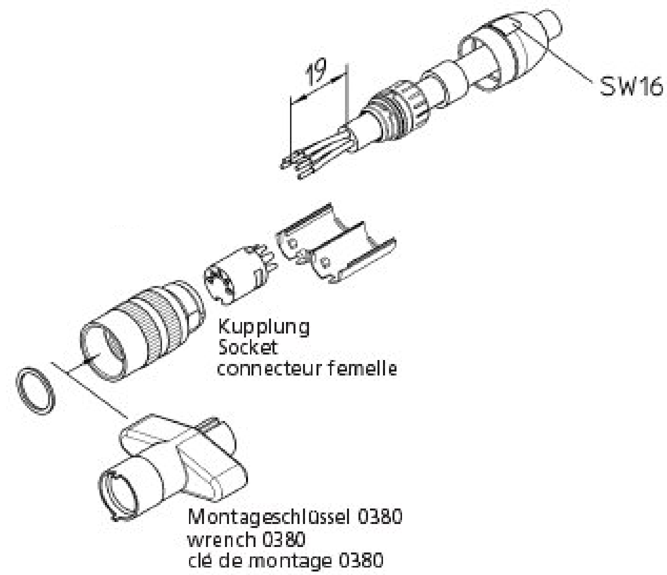


Fig. A Five pin connector is shown. Use same process for 3 pin.

MATERIAL

ITEM	PART NO.	MANUFACTURER	DESCRIPTION
1	F3B20706	Belkin	Serial Direct Cable Db9, F/F 6'.**
2	0321 03 or 0322 03 (fig. A)	Lumberg USA	3 Pin Field Connector, Female

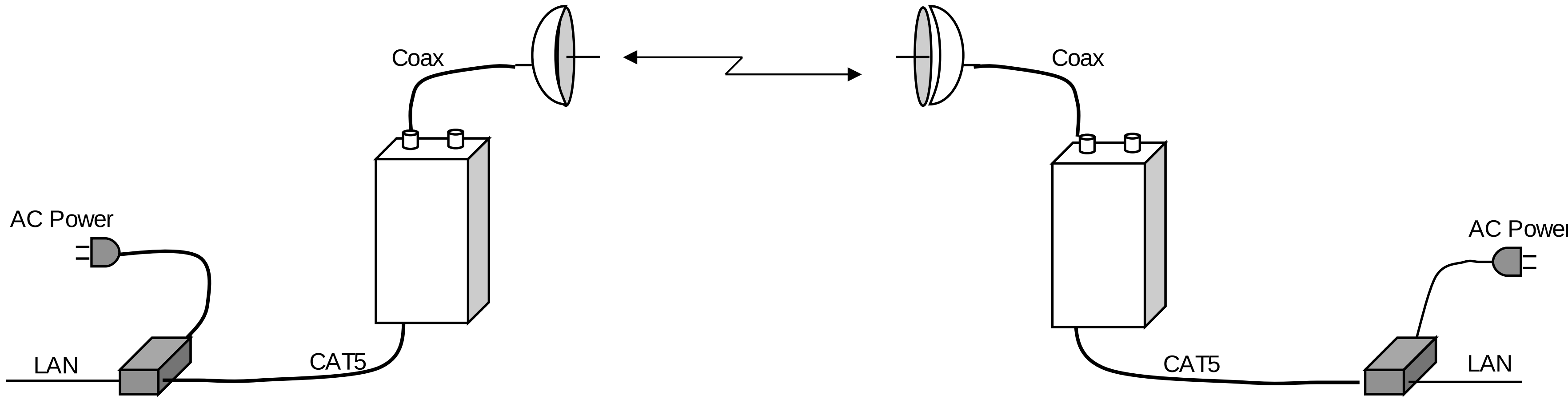
** 6' cable cut in ½ will make two cables.

DRAWN BY J. Becker	DATE 9-16-2003	**AFAR Communications, Inc.**	
CHECKED BY	DATE	TITLE **3 Pin Console Cable**	
APPROVED	DATE	DRAWING NO. CBL-0403-XXX	REV A
APPROVED	DATE	SCALE NONE	SHEET OF 1

APPENDIX E – Quick Setup Examples

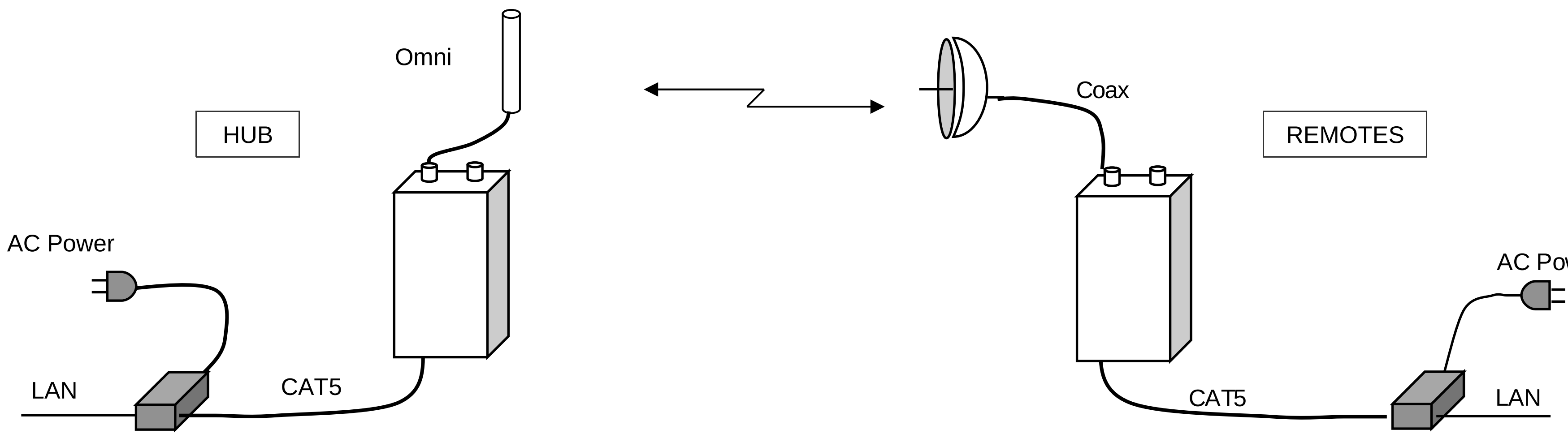
The next pages show examples on how to configure the *pulsAR* radios to deploy various topologies

Wireless Point to Point Bridge
Quick Setup Example



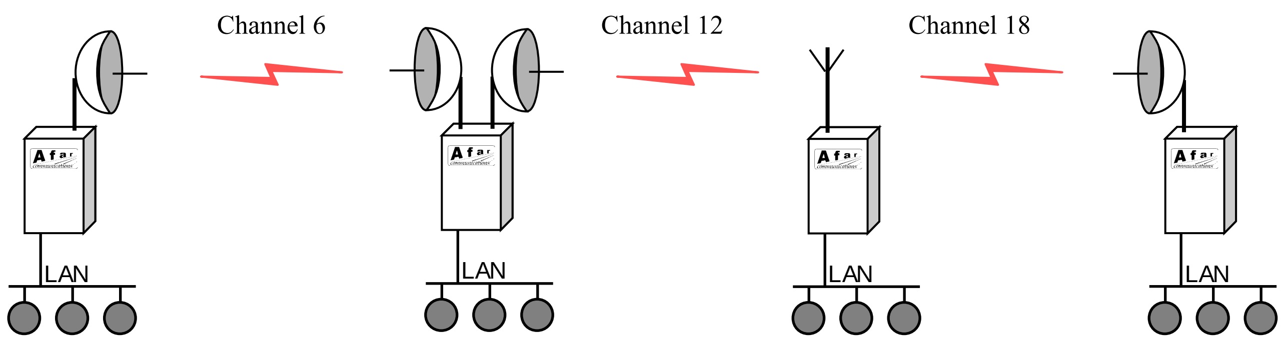
	Minimal Configuration	
>load factory >node hub >node max-children=1 >save		>load factory >save
	Changing RF Channels (optional)	
>rf1 rec=18 tr=18		>rf1rec=18
	Changing Tx Power (optional)	
>rf1 power=23		>rf1 power=23
	Checking Link Operation	
>show radios >monitor-link		>show radios >monitor-link

Wireless Point to Multi-Point Bridge
Quick Setup Example



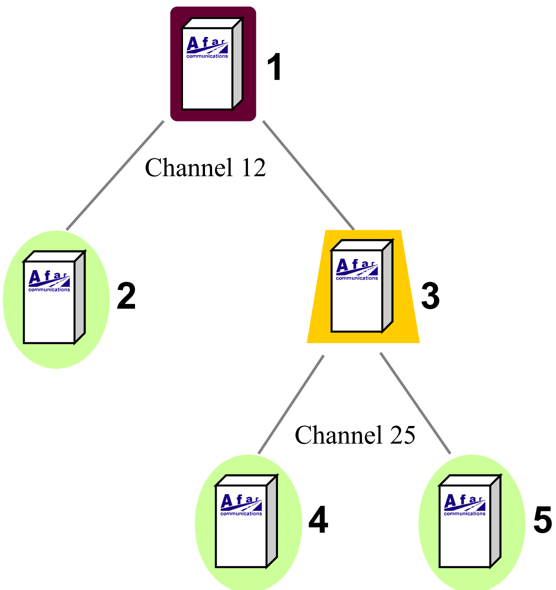
		Minimal Configuration		
	>load factory >node hub >save		>load factory >save	
		Changing RF Channels (optional)		
	>rf1 rec=18 tr=18		>rf1 rec=18	
		Changing Tx Power (optional)		
	>rf1 power=23		>rf1 power=23	
		Verifying Network Operation		
	>show radios			

Wireless Linear Network
Quick Setup Example



Leftmost node	Middle (2 antennas)	Middle (single antenna)	Rightmost
>load factory	>load factory	>load factory	>load factory
>node type=root-1	>node type=branch	>node type=branch	>node type=leaf
>node max-children=1	>node max-children=1	>node max-children=1	
>rf1 ant=b tr=6 rec=6	>rf1 ant=a rec=6	>rf1 ant=a rec=12	>rf1 ant=a rec=18
	>rf2 ant=b tr=12 rec=12	>rf2 ant=a tr=18 rec=18	
>save	>save	>save	>save

Wireless Tree Network
Quick Setup Example



	Antennas A	Antennas B
1 – root	Omni	not used
2 – leaf	Directional (point to 1)	not used
3 – branch	Directional (point to 1)	Omni
4 – leaf	Directional (point to 3)	not used
5 – leaf	Directional (point to 3)	not used

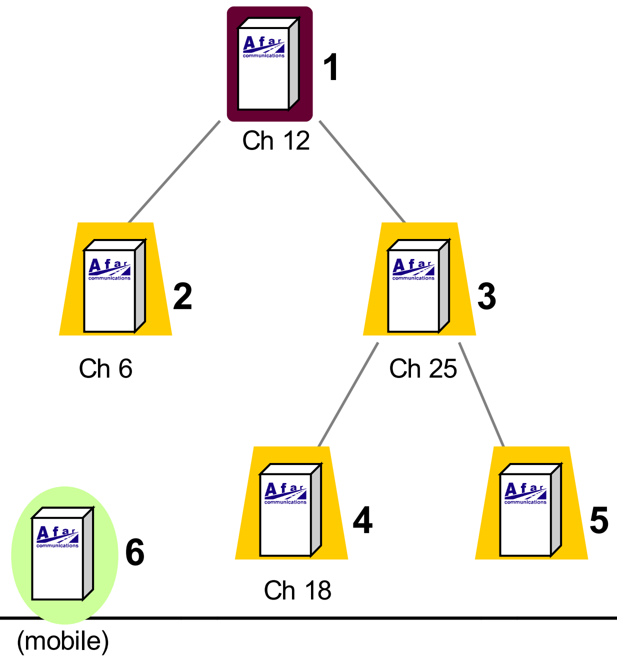
Minimum Configuration

1	**2**	**3**	**4 and 5**
>load factory >node type=root-1 >rf1 tr=12 rec=12 (1) >save	>load factory >node type=leaf >rf1 rec=12 (1) >save	>load factory >node type=branch >rf1 rec=12 (1) >rf2 tr=25 rec=25 (1) >save	>load factory >node type=leaf >rf1 rec=25 >save

Note 1: Channel 12 and 25 are the defaults for rf1 and rf2 configurations. These commands are not necessary if you plan to use those defaults.

At any node use command ">show tree" to view the complete network and key statistics for each link

Wireless Tree Network and Roaming
Quick Setup Example



	Antennas A	Antennas B
1 – root	Omni	not used
2 – branch	Directional (point to 1)	Omni
3 – branch	Directional (point to 1)	Omni
4 – branch	Directional (point to 3)	Omni
5 – branch	Directional (point to 3)	Omni
6 - leaf	Omni	not used

Minimum Configuration

Note 1: Channel 12 and 25 are the defaults for rf1 and rf2 configurations. These commands are not necessary if you plan to use those defaults.

At any node use command “>show tree” to view the complete network and key statistics for each link.

At the mobile use the command “>monitor-roam” to see the signal strengths and verify the roaming operation as the signal strengths vary.